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DEPLOYMENT REQUIREMENTS FOR U.S. COAST GUARD POLLUTION RESPONSE--ETC(U)
FEB 79 J BELLANTONI, J GARLITZ, R KODIS

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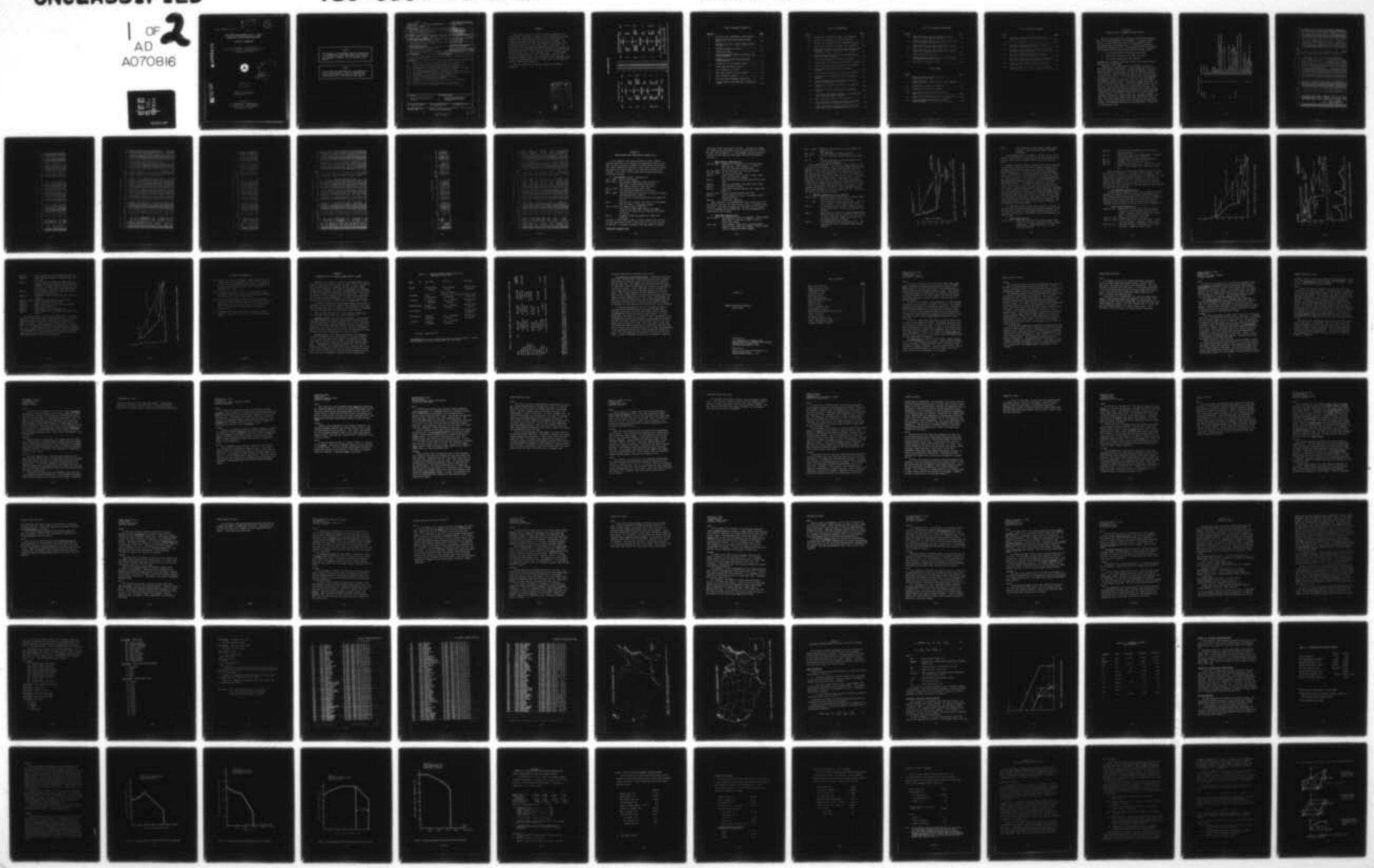

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NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

REPORT NUMBER CG-D-14-79, II

DEPLOYMENT REQUIREMENTS FOR U.S. COAST GUARD POLLUTION RESPONSE EQUIPMENT

Volume II: Appendixes

U.S. Department of Transportation
Research and Special Programs Administration
Transportation Systems Center
Cambridge MA 02142

FEBRUARY 1979

FINAL REPORT

DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Office of Research and Development
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This is the second of two volumes. Volume I contains the major analysis and conclusions.

16. Abstract

The volume contains 13 technical appendixes dealing with:

1. The Major Oil Spill Information System (data base);
2. Outflow rates from seven massive tanker oil spills;
3. Distribution of US Coastal Tanker traffic in ~~1958~~ 1985;
4. Narratives of 17 selected oil spills, 1967-1978;
5. A list of debarkation ports, with figures, in the U.S.;
6. Load/Range Tradeoff curves for the USCG HH3-F and C130 aircraft;
7. An analysis of availability of USCG towing vessels;
8. Maps of USCG installations and DOD air bases;
9. The spill potential data base employed in Volume I;
10. A model for distribution of equipment;
11. An analysis of the probabilities of large and simultaneous spills;
12. A list of non-USCG pollution response capabilities; and
13. A brief review of the behavior of surface oil slicks.

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PREFACE

This report is one of a series of studies conducted by the United States Coast Guard in support of the Presidential initiative of March 1977, concerning the ability of the United States to respond to the threat of larger oil spills in U.S. waters. The study was directed by the U.S. Coast Guard Office of Research and Development and Office of Marine Environment and Systems. The authors wish to acknowledge with thanks the expert and indispensible assistance rendered by these Offices throughout the project, and in particular that of Cdr. J.T. Leigh/GDOE, Cdr. J.L. Valenti/GWEP, Lt. R.V. Harding/GDSA and Lt. G.D. Marsh/GDOE. They are also indebted to numerous Coast Guard personnel, both at headquarters and in the field organizations, who were enthusiastic in the provision of data, advice and information.

This, the second of two volumes, contains the technical Appendixes.

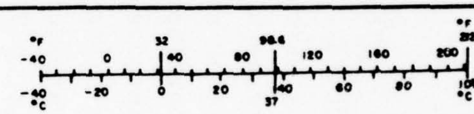
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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APPENDIX A:
MAJOR OIL SPILL INFORMATION SYSTEM (MOSIS)

The data base assembled for this study has been designated the Major Oil Spill Information System (MOSIS). It contains information on all identifiable oil spills of 50,000 gallons or more affecting waters in and around the U. S. during the period from January 1974 through July 1977. The primary sources of information for the MOSIS file were Coast Guard maintained records, namely:

a. The Pollution Incident Reporting System (PIRS)

b. The National Response Center (NRC) case files

c. The On Scene Coordinator (OSC) Reports.

Supplementary information from other sources was included wherever possible and so identified.

The MOSIS file is reproduced in this Appendix following a sheet defining the coded entries. Further explanation of the first few entry columns is given here. The TSC file number is constructed as follows: The first digit (5) indicates that the data base is restricted to spills of 50,000 gallons or more; the second digit identifies the year (e.g., 4 = 1974); and the next three represent the sequential number of the spill, with a P as the third digit identifying a potential spill. The NRC file number consists of two parts: the first three digits are the case number and the last two the year. The PIRS file number also consists of two parts: the first two digits indicate the Coast Guard district involved and the remaining five digits represent the sequential oil spill count within that district. The "Other" column is to be used to identify incidents contained in filing systems other than NRC and PIRS. The entry CG in this column refers to the Coast Guard Vessel Casualty File. The entries PDS and SDS refer to primary and secondary data sources. The remaining headings are self-explanatory. Entries are in chronological order.

MOSIS CODING SHEET

NAME	CODE	DESCRIPTION
PDS/SDS	N	NRC REPORT
	P	PIRS
	O	OSC REPORT
	U	USGS
	E	EPA
	A	OTHER
TYP	G	GROUNDING
	C	COLLISION
	R	RAMMING
	S	SINKING
	B	BREAKUP, BLOWOUT, RUPTURE, STRUCTURAL FAILURE
	T	TRANSFER ACCIDENT (TO OR FROM VESSEL)
	L	LEAKAGE OF DISCHARGE (ACCIDENTAL OR DELIBERATE)
	F	FIRE
	E	EXPLOSION, OR FIRE AND EXPLOSION
	O	OTHER
	U	UNKNOWN
LOC	S	SHELTERED OR SEMI-SHELTERED WATERS
	O	OPEN WATERS
	R	RIVERS (WITH CURRENTS > 1 KNOT)
	X	OUTSIDE THE USCG OSC RESPONSIBILITY
CATEGORY	1	ONSHORE TRANSPORTATION PIPELINE
	2	ONSHORE NON-TRANSPORTATION
	3	U.S. FLAG TANKERS AND BULK CARRIERS (CARRYING PETROL)
	4	FOREIGN FLAG TANKERS AND BULK CARRIERS (CARRYING PETROL)
	5	BARGES AND TANK BARGES
	6	VESSELS OTHER THAN 3,4,AND 5
	7	UNDERWATER WELLS
	8	UNDERWATER PIPELINES
	9	ONSHORE TRANSPORTATION OTHER THAN 1
	0	OTHER OR UNKNOWN

MAJOR OIL SPILL INFORMATION SYSTEM

TSC	NAC	PIRS	OTHER	P D S	S D S	L O C	T Y P	LOCATION	DIST SHR	LATN	LONGW	POLL	OCC DATE	BODY OF WATER	AMT DISCH KGALS	AMOUNT IN WAT KGALS	SOURCE	CAT	CAUSE	PREOSC
54001		0300014		P		X		TRENTON NJ	0	4010	7444	DSTLL	0104	DELAWARE R	600	20	MOBILE OIL CO	2	PRSNERR	C PHIL
54002		0802185		P		X		LONGVIEW TX	C	3230	9443	CRUDE	0110	SABINE R	72		ONSHORE PIPELN	1	PPLNRUP	EPA VI
54003		0804755		P		R		N ORLEANS LA	0	2959	9015	GAS	0110	MISS. RIVER	120		BULK STORAGE	2	HOSERUP	C N ORL
54004		0804824	CG	P	A	R	C	N IBERIA LA	0	3004	9145	CRUDE	0115	MISS. ML120	158	158	MV COLUMBIA	3	COLLSN	C N ORL
54005		0801920	CG	P	A	R		DNLDSNVIL LA	0	2955	9105	CRUDE	0118	MISS. ML119.5	1680	80	SHELL OIL CO	1	PPLNRUP	C N ORL
54006		0300075		P		R	G	YONKERS NY	0	4047	7356	#6	0119	HUDSON RIVER	84	84	TB1000-9999GT	5	GROUND	C ALBNY
54007		0300098		P		X		PATERSON NJ	0	4102	7402	#6	0123		60		NON TRANS FAC	2	CORRSN	EPA II
54008		0800662		P		X		POLK TX	0	3015	9444	CRUDE	0125	L. LIVINGSTON	98		ONSHORE PIPELN	1	PPLNRUP	EPA VI
54009		0200044		P		X		SMYRNA TENN	0	3602	8635	DIESL	0126	PRCY PRIEST L	70		ONSHORE PLANT	2	STRGFLR	EPA IV
54010		0800121		P		X		POLK TX	0	3043	9456	CRUDE	0215	L. LIVINGSTON	168		ONSHORE PIPELN	1	PPLNRUP	EPA IV
54011		0300195	CG	P	A	R	C	PAULSBORO NJ	0	3951	7517	#6	0219	DELAWARE R	285	285	MV ATHOS	3	COLLSN	C PHIL
54012		0800438		P		X		DECATUR TX	0	3320	9750	CRUDE	0311	BRIDGEPORT L	126		ONSHORE PIPELN	1	PPLNRUP	EPA VI
54013		0800499		P		X		PASADENA TX	0	2944	9523	GAS	0311		63		ONSHORE PIPELN	1	PPLNRUP	EPA VI
54014		0802210		P		X		JACKSON MISS	0	3239	9018	CRUDE	0329	FSS BINTC FCS	121		ONSHORE PRODUC	2	PIPERUP	EPA VI
54015		0900162	CG	P	A	R	G	ALXNDR BAY NY	0	4430	7546	CRUDE	0415	ST LAWRNC RIV	147	147	TSIMPRI SARNIA	3	GROUND	C BUFFL
54016				U		O	B	EUG I BLCK LA	C	2800	9000	CRUDE	0417	GLF OF MEXICO	840	840	OFFSHORE PROD	8	PPLNRUP	USGS
54017		0801087		P		X		WOODVILLE TX	0	3047	9426	CRUDE	0429		176		ONSHORE PIPELN	1	CRASH	EPA VI
54018		1100442		P		X		WELTER ARIZ	0	3310	11410	DIESL	0507	GILA RIVER	60		BULK RAIL VEH	9	UNKNOWN	EPA IX
54019		1100448		P		X		BAKERSFLD CA	C	3520	11910	CRUDE	0508	KERN RIVER	714		ONSHORE PIPLN	1	PIPERUP	EPA IX
54020		0802214		P		X		TYLER TX	0	3228	9516	CRUDE	0520		50		ONSHORE PIPELN	1	PPLNRUP	EPA VI
54021				O		X	C	CINCINNATI OH	0	3735	8415	KRSNF	0522	OHIO RIVER	73	73	BARGE EIDC #1	5	COLLSN	C CINC.
54022		0801837		P		X		MARSHALL TX	C	3237	9407	CRUDE	0621		63		ONSHORE PIPELN	1	CRASH	EPA VI
54023	00575			N		R	S	N ORLEANS LA	0	2950	9055	CRUDE	0625	MISS. ML106	84	84	TB ABC 2311	5	SINKING	C N ORL
54024		0801818		P		X		TYLER TX	0	3236	9513	CRUDE	0627		332		ONSHORE PIPELN	1	PPLNRUP	EPA VI
54025	00675	0803895		N	P	S	S	GALVESTON TX	C	2937	9500	#6	0708	BAYPORT CHNNL	378	378	TB TM 10	5	SINKING	P HSTN
54026		0900343		P		X		PARMA OHIO	0	4129	8141	GAS	0715		187		ONSHORE STORGE	2	FLNGFLR	EPA V
54027		0300921		P	A	S	G	RED HOOK NY	0	4202	7356	GAS	0719	HUDSON RIVER	130	130	TB HYGRADE2	5	GROUND	C N YRK
54028		0801834		P		S	C	PORT ARTHR TX	0	2950	9357	#6	0721	SABINE LAKE	84	84	TB 1-10K	5	COLLSN	M P ART
54029	00375	0300986		N	P	S		GLENMOUNT NY	0	4235	7346	#2	0731	HUDSON RIVER	940	100	BULK TRANSFER	2	TKOVRFL	C ALBNY
54030	00275			N		X	C	BANNER IL	0	4015	9010	#2	0804	ILL R ML139	92	92	TB IOI #162	5	COLLSN	M ST LO
54031	01175	0801956		N	P	S		BEAUMONT TX	0	3002	9355	GAS	0805	NECHES RIVER	84		COLONIAL PIPLN	1	PPLNRUP	C SABIN
54032	03075			N		X	G	GRAYS PT MO	0	0	0	TLUEN	0812	MISS. RIVER	65	65	TB UBC 241	5	GROUND	EPA VII
54033	04075	0802192		N	P	X		ABILENE TX	0	3228	9945	#4	0817	STOCK POND	54	54	6" LINE	1	LINERUP	EPA VI
54034		0802216		P		X		WCHTA FLLS TX	0	3353	9830	CRUDE	0822	WICHITA RIVER	63		BULK STORAGE	2	IMPHNDL	EPA VI
54035	06975			N	U	O	B	CHNDLUR IS LA	0	3003	8852	CRUDE	0909	GLF OF MEXICO	92	92	PIPELINE	8	PPLNBRK	C N ORL
54036	11475	0301289		N	P	S	G	NEW HAVEN CT	0	4118	7255	#6	1006	N HAVEN HRBR	105	105	MV MSSNK BRGN	3	GROUND	C N HVN
54037	11875	0802686		N	P	S		CORP CHRST TX	0	2749	9726	#6 CR	1009	CORP CHRST HR	307	307	TS 20-35K	3	UNDETRM	C CR CH
54038	13475			N		X	G	DNLDSNVLL LA	0	2955	9105	CRUDE	1021	MISS. ML176	92	92	MV CRCOLE(IT)	4	GROUND	C N ORL
54039	13675	0900513		P	N	R		TONOWANDA NY	0	4300	7854	GAS	1027	NIAGARA RIVER	73		BULK TRANSFER	2	PUMPFLR	C BUFFL
54040	18975	0900571		N	P	R	S	ALXNDR BAY NY	0	4420	7556	DIESL	1121	ST LWRNC RIVR	53		MV ROY A JODEY	3	SINKING	C BUFFL
54041	20375	0804145		N	P	S		CORP CHRST TX	0	2749	9725	CRUDE	1202	CORP CHRST HR	51	51	ONSHORE PIPELN	1	RUPTURE	C CR CH
54042				O		X	3	MARIETTA OH	0	3923	8126	OIL	1212	OHIO RIVER	100	100	UNDRGRND LEACH	2	SEEPAGE	M HUNT.
54043	23675			N		R		MISS. RIVER	0	2900	9014	CRUDE	1224	MISS. ML89	63	63	BARGE TRANS CO	5	TKOVRFL	C N ORL
54P01		0300024		P		S	C	WILMNGTON DL	0	3947	7435	CRUDE	0104	ATLANTIC	0	50P	TS 10-20K	3	COLLSN	C PHIL
54P02		0300160		P		S		FIRE I NY	0	4040	7308	MXPTR	0207	ATLANTIC	0	330P	TS 500-999 GT	3	PRSNERR	C N YRK
54P03		1100174		P		O	G	PNT LOMA CA	0	3239	11714	#6	0215	PACIFIC	0	5880P	TS 10-20K	3	GROUND	M SAN D
54P04		1100175		P		O	B	S CLEMENTE CA	0	3348	11818	DIESL	0216	PACIFIC	0	50P	OFFSHR TS PPLN	8	PIPERUP	C LA

MAJOR OIL SPILL INFORMATION SYSTEM

ISC	NRC	PIRS	OTHER	P D S	S D S	L O C	T Y P	LOCATION	DIST SHR	LATN	LONGW	POLL	OCC DATE	BODY OF WATER	AMT DISCH KGALS	AMOUNT IN WAT KGALS	SOURCE	CAT	CAUSE	PROSC
54P05		0700116		P		S	G	ST PTRSBRG FL	0	2747	8231	MXPTR	0226	TAMPA BAY	0	50P	DRY CARGO SHIP	6	GROUND	M ST P
54P06		0300306		P		O	G	NEW YORK NY	0	4033	7358	DIESL	0318	NY HARBOR	0	100P	TB 1000-9999GT	5	GROUND	C N YRK
54P07		0300297		P		O	G	HBFRD INLT NJ	0	3850	7437	CRUDE	0402	ATLANTIC	0	1312P	TS 50-100K	3	GROUND	C N YRK
54P08	00475			N	A	R	E	PHIL. PA	0	3957	7508	CRUDE	0408	DELAWARE RIVR	10	50P	MV ELIAS(GR)	4	EXPLOSN	C PHIL
54P09		0700363		P		S	G	MIAMI FLA	0	2546	8011	#6	0515	ATLANTIC	0	294P	UNKN/OTHER VES	3	GROUND	M MIAMI
54P10		0700369		P		O		KEY WEST FLA	0	2433	8148	DIESL	0517	ATLANTIC	0	176P	ONSHORE PLANT	2	VNDLSM	M KEY W
54P11		0300662		P		S	G	WLMNGTON DL	0	3942	7532	CRUDE	0530		0	1000P	TS 20-35K	3	GROUND	C PHIL
54P12		0300743		P		R	C	PEEKSKILL NY	0	4114	7355	MXPTR	0615	HUDSON RIVER	0	1570P	TS 10-20K	3	COLLSN	C ALBNY
54P13		0300904		P		R	G	HUDSON NY	0	4210	7351	#6	0715	HUDSON RIVER	0	6775P	TS 10-20K	3	GROUND	C ALBNY
54P14	04675			N		S	G	NEW YORK NY	0	4042	7401	#6	0824	ATLANTIC	0	18500P	MV AEOLUS(LI)	4	GROUND	C N YRK
54P15		0700864		P		S	G	TAMPA BAY FL	0	2738	8237	#6	0904	TAMPA BAY	0	300P	DRY CARGO SHIP	6	GROUND	M TAMPA
54P16		0301298		P		P	G	MRCS HOOK PA	0	3949	7525	NPTHA	1007	DELAWARE R	0	6816P	TS 10-20K	3	IMPMAIN	C PHIL
54P17	11975			N		S	G	NEW BEDFRD MA	0	4138	7055	#2	1009	BUZZARDS BAY	0	3100P	TB BOUCHARD#65	5	GROUND	M BOSTN
54P18	13275			N		X	G	SITKA AK	0	5650	13525	DIESL	1014	SITKA SOUND	0	70P	MV CLMBIA (US)	3	GROUND	CGD17
54P19		0301343		P		S	G	NEW YORK NY	1	4039	7404	#6	1019	NY HARBOR	0	100P	TS 20-35K	3	GROUND	C N YRK
54P20		0301351		P		O	G	CAPE MAY NJ	0	3839	7448	CRUDE	1023	ATLANTIC	0	4850P	TS 10-20K	3	GROUND	C PHIL
54P21	17775			N		O	G	CABOROJO PR	0	1756	6711	CRUDE	1112	CARIBBEAN SEA	0	13000P	MV DAPHINE(LI)	4	GROUND	C SAN J
54P22	17975			N		R	G	N HAMBURG NY	0	4210	7325	#6	1114	HUDSON RIVER	20	3000P	TB B 75	5	GROUND	C ALBNY
54P23		0301521		P		O	G	FALKNER I NY	0	4111	7227	#4	1210		0	5880P	TS 20-35K	3	GROUND	C N YRK
54P24		0301564		P		R		GLENMOUNT NY	0	4237	7346	#6	1217	HUDSON RIVER	0	90P	BULK FL VHCL	9	CAPSIZE	C ALBNY
54P25		0701182		P		O	G	EGMONT KEY FL	0	2737	8242	DIESL	1218	ATLANTIC	0	100P	DRY CARGO SHIP	6	GROUND	M KEY W
54P26		0701189		P		S	G	ST PTRSBRG FL	0	2746	8231	DIESL	1221	TAMPA BAY	0	100P	TGBOAT/TWBOAT	6	GROUND	M ST P

MAJOR OIL SPILL INFORMATION SYSTEM

ISC	NRC	PIRS OTHER	P D S	S D S	L O C	T Y P	LOCATION	DIST SHR	LATN	LONGW	POLL	OCC DATE	BODY OF WATER	AMT DISCH KGALS	AMOUNT IN WAT KGALS	SOURCE	CAT	CAUSE	PREOSC
55001	24575		N		R		TEXAS CITY TX	0	2923	9455	CRUDE	0104	INDSTRL CANAL	504	166	TXS CITY RFNRY	2	PPLNBRK	C GLVST
55002	25975		N	O	S	S	MIAMI FLA	0	2547	8011	DSLDK	0111	BISCAYNE BAY	90	>90	DREDGE CARPEN	6	SINKING	C MIAMI
55003	26175		N		X		PALESTINE TX	0	3140	9530	CRUDE	0107	LITTLE CREEK	210	210	6" PIPELINE	1	BRKPLNG	EPA VI
55004	27675	0700052	N	P	S	G	ST CROIX VI	0	1742	6445	CRUDE	0122	LIMETREE BAY	376	376	MV MCHL LEMOS	4	GROUND	C SAN J
55005	27775	0100828	N	P	X		W BOYLSTON MA	0	4215	7145	KRSNE	0121	WACHUSETT RES	122	UNKNWN	ONSHORE STORGE	2	PRSNERR	EPA I
55006	28175		N		R	C	N ORLEANS LA	0	2900	9013	CRUDE	0130	MISS. ML87	2814	>400	BARGES IS86/87	5	COLLSN	C N ORL
55007	29075		N		S		ABRDEEN PV GR	0	3920	7615	#2	0128	CHESAPK BAY	60	60	FUEL OIL TNK	2	INFREEZ	C BALT
55008	28875	0300151	N	P	R	E	MRCS HOOK PA	0	3948	7525	CRUDE	0131	DELAWARE R	500	50	MV CORINTHOS	4	COLLSN	C PHIL
55009		1700138	P		X		ALASKA	0	6830	14915	DIESL	0201		65		ONSHORE PIPELN	1	PIPERUP	EPA X
55010	29875		N		X	L	PACIFIC	300	3530	13000	CRUDE	0212	PACIFIC	1660	1680	MV OSWGO PATRT	3	SLOWLK	C LA
55011	30875	0900053	O	N	S	G	MILWAUKEE WIS	1	4259	8752	#5	0224	LAKE MICHIGAN	74	74	HANNAH BRG2901	5	GROUND	C MILWA
55012	32075		N		X	C	VCKSBURG MISS	0	3215	9045	CRUDE	0305	MISS. ML437.3	1600	1603	MV JOHNNY DAN	3	COLLSN	EPA IV
55013	34875	0300390	N	P	X	B	ELZBTH CTY NJ	165	3702	6749	#6	0404	ATLANTIC	6000	6000	MV SPRIN LADY	3	BRKNTWO	CGD3
55014	35375	0100421	N	P	R		REVERE MA	0	4224	7101	#6	0407	CHELSEA RVR	60	35	BULK RAIL VEH	9	INTNTNI	P BOSTN
55015	37075	0801375	N	P	F	C	N ORLEANS LA	0	2947	9053	CRUDE	0425	MISS. ML102	209	>70	BARGE BUTANE	5	COLLSN	C N ORL
55016	42675	1100615	N	P	S		L ANGELES CA	0	3343	11816	#6	0716	L A HARBOR	84	84	MV LORENZO HAL	3	VALVFLR	C LA
55017	42975	0700949	N	P	O		KEY WEST FLA	0	2433	8149	BNKER	0720	STRTS OF FLA	60	>60	MV GARBIS	3	INTNTNL	C KEY W
55018	43775	1200286	N	P	S		MARTINEZ CA	0	3801	12204	GAS	0723	SAN PABLO BAY	130		S PACIFIC PPLN	1	TANKRUP	M SAN F
55019		0803908	P	A	X		LONGVIEW TX	0	3230	9450	CRUDE	0808	SABINE RIVER	63		ONSHORE PROD	2	CRASH	EPA VI
55020	44175	0500729	N	P	S		BALTIMORE MD	0	3913	7633	#6	0810	PATAPSCO RVR	126	126	TB SHAMROCK	5	TNKOVFL	M BALT
55021	44475	0802760	N	P	X	C	OFF GLVSTN TX	69	2825	9255	CRUDE	0815	GLF OF MEXICO	840	840	MV GLOBTIC SUN	3	COLLSN	GULFST
55022		0301162	P		R		PHILA PA	0	3954	7512	#6	0914	SCHUYLKILL R	60		ONSHORE RFNRY	2	FLNGFLR	C PHIL
55023	47575		N		X		PLYMOUTH MICH	0	0	0	GAS	0926	DRNGE DITCHES	50	50	PIPELINE	1	PPLNRUP	EPA V
55024	48575	0301274	N	P	R	G	BRONX NY	0	4048	7354	#6/#4	1007	EAST RIVER	102	102	BCHRD BARGE115	5	GROUND	C N YRK
55025	48675		N		X	G	EVANSVLLE IND	0	3750	8740	GASFL	1007	OHIO R ML309	84	84	TB CHTN 2181/5	5	GROUND	M EVANS
55026	48875	1700226	N	P	X		SKAGWAY AK	0	5927	13519	GAS	1009	LYNN CANAL	300	200	ONSHRE FUELING	2	TNKCLPS	C JNEAU
55027		0803699	P	A	S		MARSH IS LA	0	2939	9200	CRUDE	1016	VIRMILION BAY	2520		ONSHORE PROD	2	WLLBLWI	C N ORL
55028		0301387	P		R		CHESTER PA	0	3951	7520	MIXED	1104	DELAWARE R	73	73	TUGBOAT	6	STRCFLR	C PHIL
55029	50975		N		O	S	LAKE SUPERIOR	1	4652	8500	BNKER	1111	LAKE SUPERIOR	70	70	MV EDMND FITZ	3	SINKING	C SSMAR
55030	51775		N		X		BORDENTOWN NJ	0	4007	7444	#2	1122	CROSSWICKS CK	250	75	COLONIAL PPLNE	1	RUPTURE	EPA II
55031	52375		N		X		CONWAY PA	0	4040	8020	#2	1204	OHIO RIVER	60	60	PENN CNRTL RR	2	BRKPPLN	EPA III
55032	53175	0701101	N	P	O	G	SAN JUAN PR	0	1829	6608	BNKER	1209	ATLANTIC	500	500	TB Z102	5	GROUND	C SAN J
55033	54175	0804325	N	P	S		TEXAS CITY TX	0	2922	9453	CRUDE	1224	TXS CITY CHNL	76	76	MV AMCO YRKTWN	3	HOSERUP	C GLVST
55034	54575		N		X		WARREN OH	0	4120	8050	OIL	1231	MAHONING RIVR	100		STORAGE TANK	2	LKNGTNK	EPA V
55P01		0300066	P		O	C	DELAWARE BAY	0	3908	7515	MXPTP	0117	DELAWARE BAY	0	9200P	TS 20-35K	3	COLLSN	
55P02		0300070	P		O	C	SANDY HOOK NJ	0	4028	7401	WSOIL	0119		0	100P	TB 1000-9999GT	5	COLLSN	C N YRK
55P03		1200039	P		S		VALLEJO CA	0	3804	12214	CRUDE	0122	SAN PABLO BAY	0	252P	TS 20-35K	3	PRSNERR	C LA
55P04		0300096	P		O	C	DELAWARE BAY	0	3909	7516	DIESL	0124	DELAWARE BAY	0	3000P	TS 20-35K	3	COLLSN	
55P05	29675		N		O		PORTSMOUTH NH	0	4305	7045	DIESL	0208	ATLANTIC	15	5500P	TS ATHNIAN STR	4	STRMDMG	C PTLND
55P06	30775		N		S	G	OAK HRBR WASH	0	4810	12405	#6	0219	JUAN DE FUCA	0	945P	MV RELIEF	3	GROUND	C STTLE
55P07		0300234	P		S	C	NEW YORK NY	1	4039	7407	#6	0227	NY HARBOR	0	100P	TS 10-20K	3	COLLSN	C N YRK
55P08		0300243	P		S	C	NEW YORK NY	1	4038	7402	MIXED	0301	NY HARBOR	0	100P	TS 20-35K	3	COLLSN	C N YRK
55P09	32475		N		X	S	PITTSBURG PA	0	4015	7958	DIESL	0308	MNNGHLA MLD.5	0	50P	MV ONWARD	3	SINKING	C PITTS
55P10	32375	0700189	N	P	O	G	SAN JUAN PR	0	1828	6607	GAS	0309	RSVLT RDS PSS	0	1500P	BRG CHEMICAL#1	5	GROUND	C SAN J
55P11		0700203	P		S	G	TAMPA BAY FL	0	2738	8237	DIESL	0314	TAMPA BAY	0	5040P	TS 10-20K	3	GROUND	M TAMPA
55P12	34375		N	A	R		ALBANY NY	0	4238	7345	#2	0329	HUDSON RIVER	40	50P	MV COLORADO	3	TANKRUP	C ALBNY
55P13		0700239	P		S	G	ST PTRSBRG FL	3	2747	8234	MIXED	0331	GLF OF MEXICO	0	500P	TS 10-20K	3	GROUND	M ST P

MAJOR OIL SPILL INFORMATION SYSTEM

TSC	NRC	PIRS	OTHER	PDS	SDS	LOC	TYP	LOCATION	DIST SHR	LATN	LONGW	POLL	OCC DATE	BODY OF WATER	AMT DISCH KGALS	AMOUNT IN WAT KGALS	SOURCE	CAT	CAUSE	PREOSC
55P14	36175			N	A	F	C	N ORLEANS LA	0	2900	9016	#3	0416	MISS. ML90	23	3000P	MV STOLT PNRER	3	COLLSN	C N ORL
55P15	38175			N		O	S	AGUADILLA PR	0	1936	6605	CRUDE	0513	ATLANTIC	0	16400P	MV EPC CICTRNS	4	SINKING	C SAN J
55P16		0300583		P		F		CAMDEN NJ	0	3955	7512	MIXED	0517	DELAWARE R	0	1000P	ONSHORE FEF	2	RUPTURE	C PHIL
55P17		0700394		P		O	G	EGMONT KEY FL	0	2735	8245	GAS	0605		0	237P	TB 10-20K	5	GROUND	M KEY W
55P18		0300971		P		X	G	GLNNS FLLS NY	0	4320	7330	GAS	0622	HUDSON RIVER	0	89P	TB 1-10K	5	GROUND	EPA II
55P19		0300836		P		O		ATLANTIC	12	3837	7449	CRUDE	0709	ATLANTIC	0	420P	TB 50-100K	5	PRSNFRR	
55P20		0300838		P		S	G	NEW YORK NY	0	4039	7402	CRUDE	0710	NY HARBOR	0	10000P	TS 100K	3	GROUND	C N YRK
55P21	42375			N		O	G	CAPE MAY NJ	0	3856	7456	#6	0712	ATLANTIC	0	5000P	M/T OLYMPC DAL	3	GROUND	C PHIL
55P22		0700571		P		S	G	ST PTRSBRG FL	0	2747	8232	#4	0804	TAMPA BAY	0	60P	DRY CARGO SHIP	6	GROUND	M ST P
55P23	44875			N		R		PHILA PA	0	3957	7508	MIXED	0818	SCHUYLKILL R	0	10000P	GULF OIL CO	2	FIRE	C PHIL
55P24		0301052		P		R		CHESTER PA	0	4005	7520	MIXED	0819	DELAWARE R	0	9870P	ONSHORE FEF	2	TANKRUP	C PHIL
55P25		0301197		P		S	G	NEW YORK NY	0	4038	7404	CRUDE	0919	NY HARBOR	0	10000P	TS 50-100K	3	GROUND	C N YRK
55P26	48975	0301285		N	P	F	G	DELAWARE BAY	0	3850	7501	GAS#2	1010	DELAWARE RVR	0	14000P	MV TXCO CALIF	3	GROUND	C PHIL
55P27		0301293		P		R		CHESTER PA	0	4006	7520	OIL	1011	DELAWARE R	0	2000P	ONSHORE FEF	2	TANKRUP	C PHIL
55P28	53575			N		S	C	HMPTN RDS VA	0	3712	7615	BNKER	1214	CHSPK BAY	0	80P	MV VANIG HRZN	3	COLLSN	M HM RD
55P29		0301581		P		O	G	CAPE MAY NJ	3	3850	7450	CRUDE	1229	ATLANTIC	0	10000P	TS 100K	3	GROUND	C PHIL
55P30		0301579		P		S	G	NEW YORK NY	0	4047	7355	DIESL	1230	NY HARBOR	0	693P	TB 1-10K	5	GROUND	C N YRK
55P31	00276			N		X	G	KAYAK IS AK	0	0	0	DIESL	1231	GLF OF ALASKA	0	100P	FV SAMRGA(UR)	4	GROUND	CGD17

MAJOR OIL SPILL INFORMATION SYSTEM

ISC	NRC	PIRS OTHER	P D S	S D S	L O C	I Y P	LOCATION	DIST SHR	LATN	LONGW	POLL	OCC DATE	BODY OF WATER	AMT DISCH KGALS	AMOUNT IN WAT KGALS	SOURCE	CAT	CAUSE	PREOSC
56001	00176	0301567	N	P	R	C	TARRYTOWN NY	0	4110	7405	#2	0102	HUDSON RIVER	90	90	TB DELAWARE	5	COLLSN	C N YRK
56002	00376		N		S		BROOKLYN NY	0	4040	7400	#6	0105	GOWANUS CANAL	2000	2000	RICHG OIL TERM	2	FIREXP	C N YRK
56003	00576		N		X		PRKRSBRG W VA	0	3920	8130	OIL	0107	LTHRWOOD CR	57	57	EUREKA PIPELN	1	HLNPPIN	EPA III
56004		0200646	P		X		SEMINOLE OK	0	3510	9630	CRUDE	0107		572		ONSHORE PIPIN	1	PIPERUP	EPA VI
56005		0200041	P		X		SHLBYVILLE IL	0	3920	8850	CRUDE	0108	ROBINSON CR	366		ONSHORE PIPELN	1	PIPERUP	EPA VI
56006	01876		N		X		SHLBYVILLE IL	0	3924	8850	CRUDE	0113	ROBINSON CR	210	210	CHICAP PIPEIN	1	PPLNRUP	EPA V
56007	04576	0500064	N	P	O	S	CHESPKE BAY	0	3750	7609	#6	0202	CHESPKE BAY	250	250	BARGE STC101	5	SINKING	M HMP R
56008		0886423	P		X		STONEWALL TX	0	3315	10015	CRUDE	0209	WHITE RIVER	168		ONSHORE PIPELN	1	PIPERUP	EPA VI
56009	03676		N		X	C	LACON IL	0	4102	8922	JTFUL	0209	ILLINOIS RIVR	225	225	TB FLORIDA	5	COLLSN	EPA V
56010	04276	0802119	N	P	S	B	BURAS LA	2	2925	8932	CRUDE	0214	CALFORNIA BAY	56	56	OFFSHORE PROD	8	PIPERUP	C N ORL
56011	05676	0900085	P	N	S		SUPERIOR WIS	0	4644	9207	DIESL	0221	ST LOUIS BAY	90		ONSHORE STRGE	2	VALVFLR	C DULTH
56012	06376		N		E		CHALMETTE LA	0	0	0	CRUDE	0225	MISS. RIVER	84	84	BARGE SJT4	5	CRKNHLL	C N ORL
56013	07076	0803001	N	P	S	E	GIBSON LA	0	2938	9056	CRUDE	0301	BAYOU BLACK	59	59	TB 1-10K	5	EXPLOSN	C N ORL
56014	07276		N		X		BRADFORD PA	0	4155	7840	#2	0303	KENDALL CR	84	84	5" PIPELINE	1	LINERUP	EPA III
56015	09376	0200667	N	P	X		MARTNSVILE IL	0	3920	8750	CRUDE	0401	EMBARRAS RVR	1764	966	ONSHORE PIPELN	1	MNFDPLR	EPA V
56016	10576		N		X		PITTSBURG PA	0	4016	7958	#2	0409	MNNGHLA RIVER	150	150	EGO RR	9	VLVIPTO	EPA III
56017		0200559	P		X		ANADARKO OK	0	3503	9822	OIL	0413	WASHITA RIVER	168		ONSHORE PROD	2	EQPFLR	EPA VI
56018	12076	0300474	N	P	R	C	WESTVILLE NJ	0	3953	7509	NPTHA	0429	DELAWARE RIVR	84	84	MV TEXACO ILL	3	COLLSN	C PHIL
56019		0300487	P		X		PLATTSBRGH NY	0	4442	7328	DIST	0502	LAKE CHMPLN	70		ONSHORE STRGE	2	PUMPFLR	EPA II
56020	12276	0830502	N	P	S		GALVESTON TX	0	2930	9453	#6	0504	GALVESTON BAY	210	210	TB NMS 3105	5	STRCFLR	C GLVST
56021	12776	0300561	N	P	X		SHELBURNE VT	0	4424	7313	GAS	0518	LAKE CHMPLN	65		ONSHORE STRGE	2	VALVFLR	EPA I
56022	12976	0900256	O	P	O	C	CLEVELAND OH	0	4129	8144	BNKER	0519	LAKE ERIE	123	123	TB L-17	5	COLLSN	C CLEVL
56023	13476	0300588	N	P	E		JERSEY CTY NJ	0	4044	7405	#6	0526	HACKENSAC RVR	5000	>70	ONSHORE STRGE	2	TANKRUP	C N YRK
56024		0886628	P		X		LONGVIEW TX	0	3245	9525	CRUDE	0603	SABINE RIVER	84		ONSHORE PIPELN	1	PPLNRUP	EPA VI
56025	14776		N		E	G	WELLSLEY I NY	0	4407	7600	#6	0623	ST LWRNCE RVR	307	307	TB NEPCO 140	5	GROUND	M BFFLO
56026	15676	0100025	N	P	O		ST JHN NB CAN	0	4518	6559	CRUDE	0629	BAY OF FUNDY	84	84	MV JL GREY(LI)	4	PABTHOS	M PRTLD
56027	15776		N		X		WHITEHSE FLA	0	0	0	WSOIL	0629	ORTEGA RIVER	120	>120	WASTE OIL PIT	2	FLOOD	EPA IV
56028	15976		N		R	C	N ORLEANS LA	0	2902	9017	#5	0708	MISS. M192.5	84	84	B GLF STTS3002	3	COLLSN	C N ORL
56029		0820730	P		O		GLF OF MEXICO	0	2600	9710	MIXED	0716	GLF OF MEXICO	53		UNKNOWN VESSEL	0	UNKNOWN	C N ORL
56030	17076		N		X		EAST BRADY PA	0	4058	7942	CRUDE	0809	ALLEGHENY RVR	184	184	TANK CARS	9	DERLMNT	EPA III
56031	18576		N		X		HAVERFORD PA	0	0	0	WSOIL	0916	NAYLOR'S RUN	80	>80	WASTE OIL STRG	2	SEEPAGE	EPA III
56032	19676		N		X	G	NIKISHKA AK	0	0	0	JP-4	1005	COOK INLET	210	210	USNS SLFT PAC	6	GROUND	M ANCHR
56033		0301256	P		X		TROY NY	0	4250	7345	GAS	1010	HUDSON RIVER	150		ONSHORE TRANSF	9	TANKRUP	EPA II
56034	99999	0851006	P		X		MOBILE ALA	0	3045	8803	ASPHL	1012	MOBILE BAY	4956		ONSHORE STRGE	2	TANKRUP	EPA IV
56035	21276		N		S	G	PRTH AMBOY NJ	0	4028	7415	CRUDE	1029	ARTHUR KILL	75	75	MT RICHARD SVR	3	GROUND	C N YRK
56036	22876	0700966	N	P	X		BALBOA HTS CZ	0	0	0	BNKER	1116	PANAMA CANAL	70	70	ONSHORE PIPELN	1	CPLNFLR	PAN C Z
56037		0831120	P		S		TEXAS CITY TX	0	2922	9454	GAS	1129	TEXAS CITY CH	168		ONSHORE PIPELN	1	PPLNRUP	C GLVST
56038	24076	0103073	N	P	O	G	NANTCKT SHLS	27	4101	6927	#6	1215	ATLANTIC	7600	7600	MV ARGO MRCHNT	4	GROUND	M BOSTN
56039	24376	1101114	N	P	S	E	L ANGELES CA	0	3343	11816	#6	1217	L A HARBOR	1000	>20	MV SANSINENA	3	EXPLOSN	C LA
56040		0812139	P		O	B	GLF OF MEXICO	0	2821	9130	DIESL	1218	GLF OF MEXICO	81	81	OFFSHORE PROD	8	PPLNRUP	C N ORL
56041	24776		N		R	G	MRCUS HOOK PA	0	3958	7507	CRUDE	1227	DELAWARE R	134	134	MV OLYMPC GAME	4	GROUND	C PHIL
56042	25576		N		O		PUERTO NVO PR	0	0	0	CRUDE	1230	ATLANTIC	349	349	TB PECK SLIP	5	OPNVALV	M SAN J
56P01		1300044	P		S		TACOMA WA	0	4716	12226	#6	0111	PUGET SOUND	0	546P	NON-TRANS FAC	2	TANKRUP	M SEATT
56P02	02576		N		O	G	SALVO NC	0	0	0	NAVYS	0118	ATLANTIC	0	84P	MV BTLGS(US)	3	GROUND	C HM RD
56P03	07776		N		O	G	SAN JUAN PR	0	1828	6607	#2	0305	ATLANTIC	33	80P	TUG GELDERLAND	6	GROUND	C SAN J
56P04		0900087	P		E		BUFFALO NY	0	4252	7850	DIST	0313	NIAGRA RIVER	0	84P	ONSHR BLK TRNS	2	TANKRUP	M BFFLO
56P05	12176	0500256	N	P	S	G	HOLLAND PT MD	0	3850	7630	DIESL	0503	CHSPKE BAY	0	370P	MV KNSHKP(IN)	4	GROUND	C BALT

MAJOR OIL SPILL INFORMATION SYSTEM

TSC	NRC	PIRS	OTHER	P D S	S D S	L O C	T Y P	LOCATION	DIST SHR	LATN	LONGW	POLL	OCC DATE	BODY OF WATER	AMT DISCH KGALS	AMOUNT IN WAT KGALS	SOURCE	CAT	CAUSE	PREOSC
56P06		0700452		P		S	B	ST PTRSBRG Fl	0	2750	8234	#6	0626	TAMPA BAY	0	6300P	TS 10-20K	3	PIPERUP	M ST P
56P07		0100237		P		S		PORTLAND ME	0	4342	7012	CRUDE	0714	ATLANTIC	0	2860P	TB 35-50K	5	STRCPLR	M PRTLD
56P08		1101026		P		O	G	SAN PEDRO CA	0	3343	11816	CRUDE	1120	PACIFIC	0	8000P	TS 50-100K	3	GROUND	C LA
56P09	22776			N		R	G	DLWRE CITY DE	0	3933	7534	CRUDE	1121	DELAWARE R	0	18900P	MV VLTERRA(S2)	4	GROUND	C PHIL
56P10	23176			N		S	G	WLFTRAP LIGHT	0	3905	7622	#6	1129	CHSPKE BAY	0	1900P	BARGE STC 411	5	GROUND	M HM RD
56P11	23376			N		X	G	KANEOHE HAWAI	0	2127	15752	JP4/5	1130	KANEOHE BAI	0	1200P	USNS NODAWAY	6	GROUND	C HONLU
56P12	23976			N		R	G	MOSS PT MD	0	3810	7640	#6	1213	POTOMAC R	0	756P	TP ELK RIVER	5	GROUND	M BALT
56P13	24676			N		R	G	CINL BEACH VA	0	3755	7615	#6	1222	POTOMAC R	0	1600P	TB STC 411	5	GROUND	M BALT
56P14	25076			N		O	G	GUAYANILL PR	0	1746	6607	CRUDE	1228	CARIBBEAN SEA	0	16000P	MV DAPHINE(LI)	4	GROUND	M SAN J
56P15		0900887		P		S		SAGINAW BAY	0	4338	8352	GAS	1228	LAKE HURON	0	55P	ONSHORE TRANS	9	DSGNFLT	

MAJOR OIL SPILL INFORMATION SYSTEM

TSC	NRC	PIRS OTHER	P D S	S D S	L O C	T Y P	LOCATION	DIST SHR	LATN	LONGW	POLL	OCC DATE	BODY OF WATER	EMI DISCH KGALS	AMOUNT IN WAT KGALS	SOURCE	CAT	CAUSE	PREOSC
57001	00977	0700062	N	P	S	C	TAMPA FLA	0	2756	8223	DIESL	0109	SPFKMAN CHANL	81	81	IB NEW YORK	5	COLLSN	M TAMPA
57002		1300225	P		X		TWIN FALLS ID	0	4236	11440	DIESL	0122	SNAKE R	55		ONSHORE PIPELN	1	PPLNRUP	EPA X
57003	02977	0103020	N	P	S	G	CLVLND LDG MA	0	4140	7039	DIESL	0128	BUZZARDS BAY	100	100	B'RGE B-65	5	GROUND	CGG WDH
57004	03577	0300115	N	P	S	G	HGHLND FLS NY	0	4121	7357	#6	0204	HUDSON R	400	400	TB ETHEL H	5	GROUND	C N YRK
57005	04577		N		X		TUSCALOOSA AL	0	3310	8748	#6	0215	BLCK WRRIOR R	50	50	TB 33(US)	5	UNKNOWN	EPA IV
57006		0200787	P		X		BRISTOW OK	0	3550	9610	DIESL	0216		84		ONSHR PIPELN	1	PIPERUP	
57007	05077		N		X	B	PACIFIC	300	3200	12800	CRUDE	0223	PACIFIC	4000	4000	MV HAWAIN PTRT	3	HULLRUP	CGD14
57008		0300200	P		X		HEMPSTEAD NY	0	4036	7340	DIESL	0227		90		ONSHR BLKSTRG	2	MALFIT	
57009	06977		N		S		JRSEY CITY NJ	0	4042	7410	#2	0305	MORRIS CANAL	70	70	PRTSIDE TRMNL	2	UNKNOWN	C N YRK
57010	07777	0200259	N	P	X	G	LOUISVILLE KY	0	3728	8542	GAS	0405	OHIO R 604.2	75	75	BRGE HINES 360	5	GROUND	M LOUIS
57011	07977		N		S		YORKTOWN VA	0	3713	7626	GSOIL	0405	UNNAMED POND	240	240	STORAGE TANK	2	RUPHOSE	M HM RD
57012		1100305	P		X		MOJAVE CA	0	3500	11800	CRUDE	0407	L A AQUEDUCT	63		ONSHORE PIPELN	1	PIPERUP	EPA IX
57013		0804146	P		X		DELCAMBRE LA	0	2954	9202	CRUDE	0423		50		ONSHORE PIPELN	1	PIPERUP	EPA VI
57014	08777	1700146	N	P	X	G	PACIFIC	0	5418	16240	DIESL	0428	PACIFIC	72	72	FISHING VESSEL	6	GROUND	CGD17
57015	09577		N		X		BRISTOL PA	0	4004	7453	OIL	0509	DELAWARE R	97	97	SPRIOR ZINC CO	2	LEACHNG	C PHIL
57016		0850506	P		O		GULF SHORES	0	3014	8740	ASPHL	0509	GLF OF MEXICO	51		UNKNOWN	0	UNKNOWN	C N ORL
57017		0867527	P		X		TRINITY TX	0	3115	9530	CRUDE	0528		395		ONSHR PIPELN	1	PIPERUP	
57018		0102084	P		O		PORTLAND ME	0	4342	7012	DIESL	0606	ATLANTIC	128		ONSHR BLKSTRG	2	TANKRUP	
57019		0820631	P		O		CORP CHRST TX	0	2749	9726	GAS	0607		218		ONSHR PIPELN	1	PIPERUP	
57020	11377		N		S		GRAND ISLE LA	0	2912	9000	CRUDE	0614	BAY MELVILLE	100	>100	PIPELINE	1	PPLNRUP	C N ORL
57021	11477	0860633	N	P	S	C	INTRC WTR WAY	0	2930	9220	#6	0626	INTCS WW M235	160	160	BARGE MM102	5	COLLSN	M FT AR
57022	11577	0500767	N	P	S	C	YORKTOWN VA	0	3713	7626	#6	0626	YORK RIVER	75	75	BRGE ATC586	5	COLLSN	M HM RD
57023		0887607	P		X		GUTHRIE TX	0	3335	10015	CRUDE	0712		147		ONSHR PIPELN	1	PIPERUP	
57024	13577	0300866	N	P	S		WEST HAVEN CT	0	4114	7256	DIESL	0717	NEW HAVEN HBR	55	55	STORAGE TANK	2	PIPERUP	C N HVN
57025	12077		N		X		JOHNSTOWN PA	0	4020	7900	OIL	0720	CONEMAUGH R	100	>100	FLOODING	2	FLOOD	EPA III
57026	12377		N		X		ANAHEIM CA	0	3350	11752	CRUDE	0727	SANTA ANA R	60	60	16" PIPELINE	1	RUPTURE	EPA IX
57027		0701667	P		S		BRUNSWICK GA	0	3105	8130	WSOIL	0727		300		ONSHR IND PLNT	2	EQUPFLR	
57028		0200783	P		X	U	MT CARMEL IL	0	3830	8750	CRUDE	0801		55		ONSHR PIPELN	1	UNKNOWN	
57029		0808022	P		S	C	INTRC WTR WAY	0	2930	9240	DIESL	0805	INTCS WW M55	63		TB 1-10K	5	COLLSN	
57030	14177		N		R	U	BAYONNE NJ	0	4035	7408	OIL	0813	PLATTY KILL C	2000	2000	BAYONNE IND	2	UNKNOWN	C N YRK
57031	13477		N		O	U	OCEAN CITY MD	0	3820	7505	BUNKC	0821	ATLANTIC	100	100	UNKNOWN	0	UNKNOWN	M BALT
57032	13977	0900729	N	P	X		OREGON OH	0	4141	8328	GAS	0910	DUCK CREEK	69	69	BUCKEYE PIPELN	1	PIPERUP	M TOLDO
57033	14077		N		R		RESERVE LA	0	2950	9100	CRUDE	0913	MISS. R M115	74	74	FIL MARQUESS	4	STKBUOY	C N ORL
57034		0201526	P		X		SPRINGFLD MO	0	3720	9325	ASPHL	0926		86		ONSHR NON-TR	2	NATPHEN	
57035		0201275	P		X		JASPER TN	0	3505	8530	DIESL	1015		90		ONSHR OIL FAC	2	INT DIS	
57036	15377		N		S		HOUSTON TX	0	2940	9458	OILCH	1026	GALVESTON BAY	300		REDWOOD CHEM	2	FIRE	EPA VI
57037	16677	0201487	N	P	X		FRANKLIN MS	0	3117	9100	CRUDE	1201	HOMOCHITTO R	294	84	8" PIPELINE	1	PIPERUP	EPA IV
57P01	00577		N		R	G	NWCASTLE ENG	0	3938	7527	CRUDE	0104	DELAWARE R	0	21000P	MT UNVRST LDR	3	GROUND	CGB GLC
57P02	01077		N		O	G	GRND T BAY MI	0	4505	8535	GAS	0111	LAKE MICHIGAN	0	2300P	MV AMCO IND	3	GROUND	C SS MR
57P03	01377		N		O	G	TNGR SOUND MD	0	3800	7555	#6	0112	TANGIER SOUND	0	608P	TB INTRSTATE17	5	GROUND	C BALT
57P04	01777		N		X		CAPE GRARD MO	0	3917	9106	#6	0116	UP MISS. M156	0	168P	TB T250-SI(US)	5	BOTTHLD	M PDUCA
57P05	07377	0500354	N	P	S	G	CUCKHOLD CR	0	3820	7630	#2KER	0329	PATUXENT R	0	200P	TB ARGL175(US)	5	GROUND	M BALT
57P06		0500373	P		S		YORKTOWN VA	0	3717	7635	DIESL	0405	YORK R	0	265P	ONSHR FUELING	2	HOSERUP	M HM RD
57P07	08277	0500604	N	P	O	G	CRLN BCH INLT	0	3355	7755	BNKER	0411	CRLN BCH INLT	0	840P	TB ATC206/207	5	GROUND	M WLMNG
57P08		0500585	P		S		CHESAPK BAY	0	3728	7617	DIESL	0519	CHESAPK BAY	0	50P	TS 0-149GT	3	PRSNERR	
57P09	15777		N		O	G	AVON NC	0	3515	7540	ASPHL	1104	ATLANTIC	0	2100P	TB MORANIA 200	5	GROUND	M HM RD
57P10	17077		N		O	C	EUGENE I LA	0	2800	9000	CRUDE	1212	GLF OF MEXICO	0	100P	HUNT OIL PLTFM	2	COLLSN	C N ORL

APPENDIX B:

OUTFLOW RATES FROM SEVEN MASSIVE TANKER SPILLS

In this Appendix seven massive tanker oil spill incidents selected from Table 4-4 of Section 4 are analyzed in order to estimate the rates at which oil entered the water during the incident. Only rough estimates are possible, in most cases, because no direct observations are usually made of oil outflow at the time of the incident. As a result, outflow rates must be deduced indirectly from several sources.

1. POLYCOMMANDER (Source: Reference 4-4)

May 5, 0330 : 49,414 tons onboard.

May 5, 0420 : Went aground, immediately began to spill oil. Spark from assisting vessel started fire. "Now appears there are three big fires."

May 6, 1530*: Fire quenched 36 hours after start.

May 7 : Fire considered terminated as of PM May 6.

May 8, 1200*: "Engineers battled to stem flow of crude oil leaking from Norwegian Motor tanker." 200 tons out of 35,000 onboard have been pumped off, slowly.

May 9 : Navy officials estimate "500 tons of oil had leaked from the tanker." Offloading stopped.

May 12, 1200*: Oil leakage stopped, apparently. "Officials estimate small vessels transferred 15,000 of the 35,000 tons of crude oil left inside the vessel."

May 16 : Estimated 20,000 tons pumped out, 15,000 tons remaining.

From May 5, 0430 to May 8, 1200*, a total of about 80 hrs, the vessel lost about 49,414-35,000 = 14,414 tons of oil to the fire and to Vigo Bay. If the Navy estimate of 500 tons leaked is correct,

*Indicates estimated time.

then about 13,900 tons burned in 36 hours. Assuming the leakage was constant over the 80 hours gives an outflow rate of 6.25 tons per hour (1875 gallons/hr.). If the leakage continued from May 8 to May 12 at the same rate, then about 1050 tons was leaked in 168 hours.

2. WAFRA (Source: Reference 4-4)

Feb. 28, 0530 :	Grounded at Pt Agulhas, No. 6 port and center tanks also No. 5 port breached. A further four port side tanks filling slowly.
Feb. 28, 1200*:	An oil slick about 1/2 mile long reported.
Feb. 28, 1800*:	Oil slick 5 miles long.
March 1, :	Slick 30 miles long. At least 2 center tanks and 4 port tanks are leaking.
March 3, :	Oil slick more than 30 miles long and five miles wide.
March 3, :	Crude oil from WAFRA "continued to foul ocean."
March 5, :	Ship continued to leak.
March 6, :	Found that a seventh tank was also leaking (See March 2).
March 8, 1517 :	Vessel refloated shortly after 3 PM.
March 8, :	Some 20 percent of cargo ... estimated to have spilled into sea.
March 9, :	32,000 tons remaining.

When refloated it was estimated that 20% or 8,000 tons of oil had spilled, from Feb. 28, 0530 to March 8, 1517, a period of about 226 hours. This gives a leakage rate, averaged over the period, of 35.4 tons/hour (10,620 gallons/hr). No oil was pumped off or burned off in the 226 hours.

3. SHOWA MARU (Reference 4-4)

Jan. 6, 0530 :	Ran aground in straits of Singapore. Master claims about 3600 kl (3168 tons) leaked in first 4-5 hours from 3 tanks.
Jan. 6, PM :	Still leaking. Master says 1 million gallons leaked so far, three tanks damaged. He also stated that the leakage had almost stopped.

Jan. 7, 1200*	:	Master says 3,300 tons (1 million gallons) has leaked so far.
Jan. 7, PM	:	"The SHOWA MARU has stopped leaking:
Jan. 13,	:	At least 4,000 tons are believed to have leaked out.
Jan. 25,	:	"Previous estimates of cargo spillage may have to be revised downward."

The estimated leakage in the first 4-5 hours comes to a rate of 633 to 792 tons per hour. If the vessel stopped leaking at say 1200 hrs on Jan. 7, then the leakage rate from 1000 Jan. 6 to 1200 Jan. 7, was about 32 tons per hour assuming that a total of 4000 tons was lost, as stated on Jan. 13. But if the total lost was the 3300 tons stated by the vessel master on Jan. 7, then the rate would be only 5 tons per hour. (See Figure B-1). From Figure B-1, it is seen that in either case there would have had to have been a dramatic drop in outflow rate from Jan. 6, to Jan. 7 if the vessel master's estimates on Jan. 6 are correct. These estimates are consistent with (a) his later statements and (b) the ultimate estimates of total loss made on Jan. 13. If correct, the initial loss rate was very high.

4. URQUIOLA (References 4-4, 4-6, and 4-8)

May 12, 1200	:	URQUIOLA grounds, 100,000 tons of crude on board. Tugs tried for an hour to free her.
1247	:	Port closed due to explosion and fire. Series of blasts reported. Still burning late in day.
May 13,	:	Oil turns water of port black. Huge oil slicks moved towards shore. 80,000 tons believed still on board.
May 14	:	Undersecretary of State for Spanish Merchant Navy said last night that "as little as 5,000 tons" of oil cargo could have seeped into the sea, with the balance going up in flames.
May 14	:	An estimated 5000 tons going toward shore. New explosion and fire; fire brought under control same day.

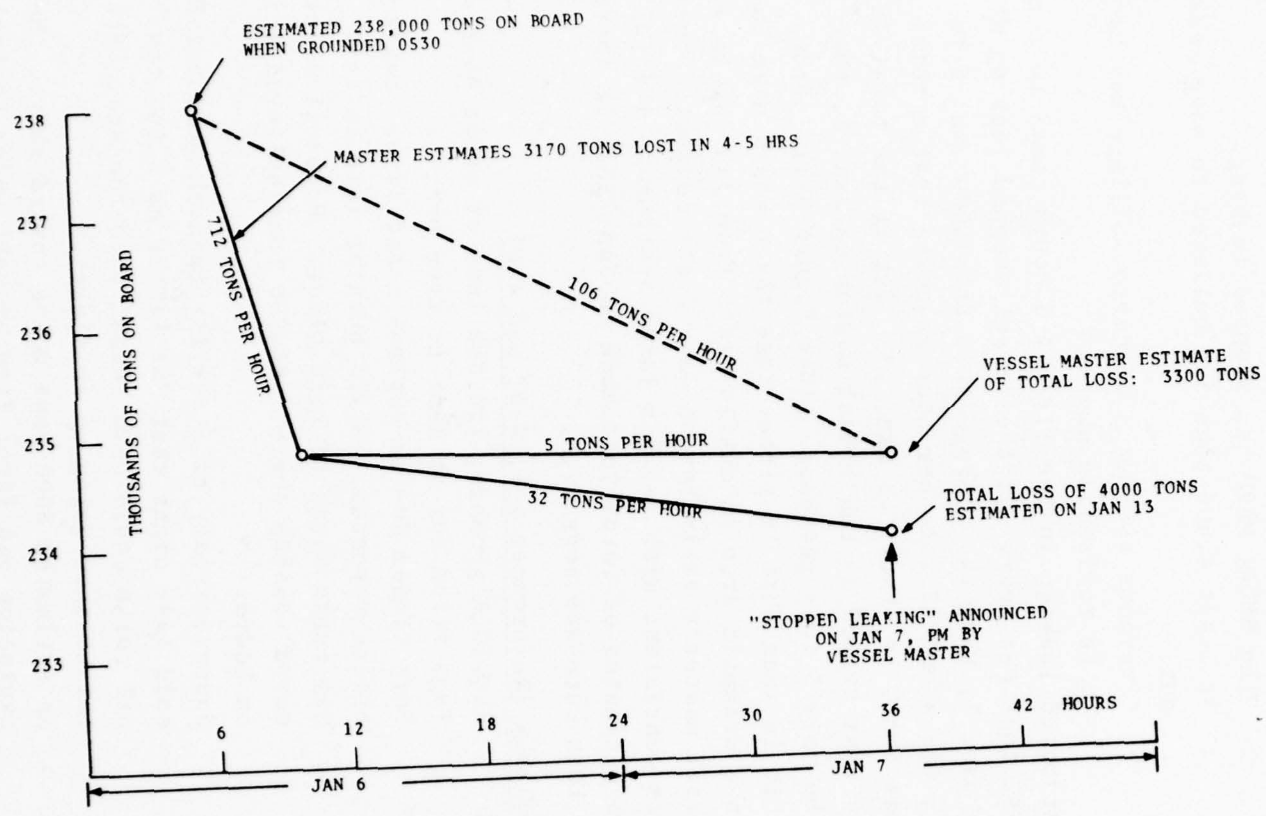

FIGURE B-1. OUTFLOW RATE ESTIMATES FOR SHOWA MARU STRANDING

May 25 : Still 9,000 tons in the vessel, salvage experts estimate. "More than 6,000 tonnes have been discharged."

If the Undersecretary's statement is correct, and if it was made at, say, 2000 May 13, then at least 5,000 tons leaked out in 32 hours, which gives an average outflow rate of 156 tons per hour.

Subsequent reports, however, report that the vessel contained 107,000 tons of crude and 3,000 tons of Bunker C, and that an estimated 100,000 tons were lost in the fire and leakage to the water (Reference B-2). Reference 4-6 notes that an estimated 25,000 - 30,000 tons of oil were washed ashore, and "most of the oil burned in the fire," which burned for a day (May 12-13) and restarted on the 14th. It is noted that the POLYCOMMANDER (50,000 DWT) supposedly burned off 14,000 tons in 36 hours, or about 10,000 tons per day. If the URQUIOLA burned at a rate of 10-20,000 tons per day for two days, then some 20-40,000 tons went up in smoke. Taking the upper figure leaves 67,000 tons to account for of the original 107,000 tons. Since there were about 9,000 tons still on board on May 25, and allowing 30,000 tons washed ashore, one obtains 28,000 tons of oil lost to the harbor directly, about the same amount as came ashore. This entire chain of conjecture yields about 58,000 tons outflow between May 12 and May 25. The corresponding outflow rate, which is also highly conjectural, is 185 tons per hour on the average.

The surprising aspect of this number, however, is that it is only 18% more than that obtained above from the statements of the Undersecretary of State for the Spanish Merchant Navy, for the first day's outflow rate. The average of the two estimates is 170 tons per hour.

5. METULA (Reference B-3)

Aug. 9, 2220 : METULA with 194,000 tons of light Arabian crude grounds at 14.5 knots, opening up 5 of her forward compartments. "About 6,000 tons of oil was initially released."

Aug. 9-19	:	"Loss of cargo increased due to the action of tides and current."
Aug. 19	:	Spring tides open 4 more compartments, resulting in an additional loss of 14,000 tons.
Aug. 20	:	Estimate total of 40,000 tons have been lost.
Sept. 19	:	Estimate total of 50,000 tons lost.
Sept. 25	:	Estimated 54,000 tons lost. (Shell Oil Co. estimate). Little leakage after refloated on Sept. 24.

Later estimates based on offloaded amounts revised the 54,000 ton figure to 51,500 tons of crude plus 2,100 of Bunker C. This gives a total of 53,600 tons lost from Aug. 9 through Sept. 24. The above history of outflow is shown in Figure B-2. The "initial release" was assumed to take 6 hrs, and the 14,000 ton loss on August 19 was assumed to take one day, with a loss of 1,000 tons from 2400 Aug. 19 to 1200 Aug. 20, when the 40,000 ton loss estimate was assumed to have been made.

6. ARGO MERCHANT (Reference B-4)

A time-history of outflow rates for the stranding of the ARGO MERCHANT (15 December 1976) was constructed from Reference B-4. This reference agrees approximately with the On-Scene Coordinator's Report for the incident with regard to oil outflows, but some differences exist between the two with regard to wave height readings, which are shown in Figure B-3 as given in Reference B-4.

7. AMOCO CADIZ (Reference 4-4)

March 16, PM :	AMOCO CADIZ, 230,000 tons of crude on board, disabled in English Channel, taken in tow by PACIFIC. Towline parted, tanker drifts toward Brest. Towline parted three times.
March 16, 2326:	Aground at 48 36 12N, 04 45 54W.
March 17, 1000:	Vessel breaks in two, pollution heave. Believe one tank ruptured. "Spillage is 50,000 tons."
March 18, (?) :	Spillage estimated at 80,000 tons, has 140,000 tons left. (Based on 220,000 total).

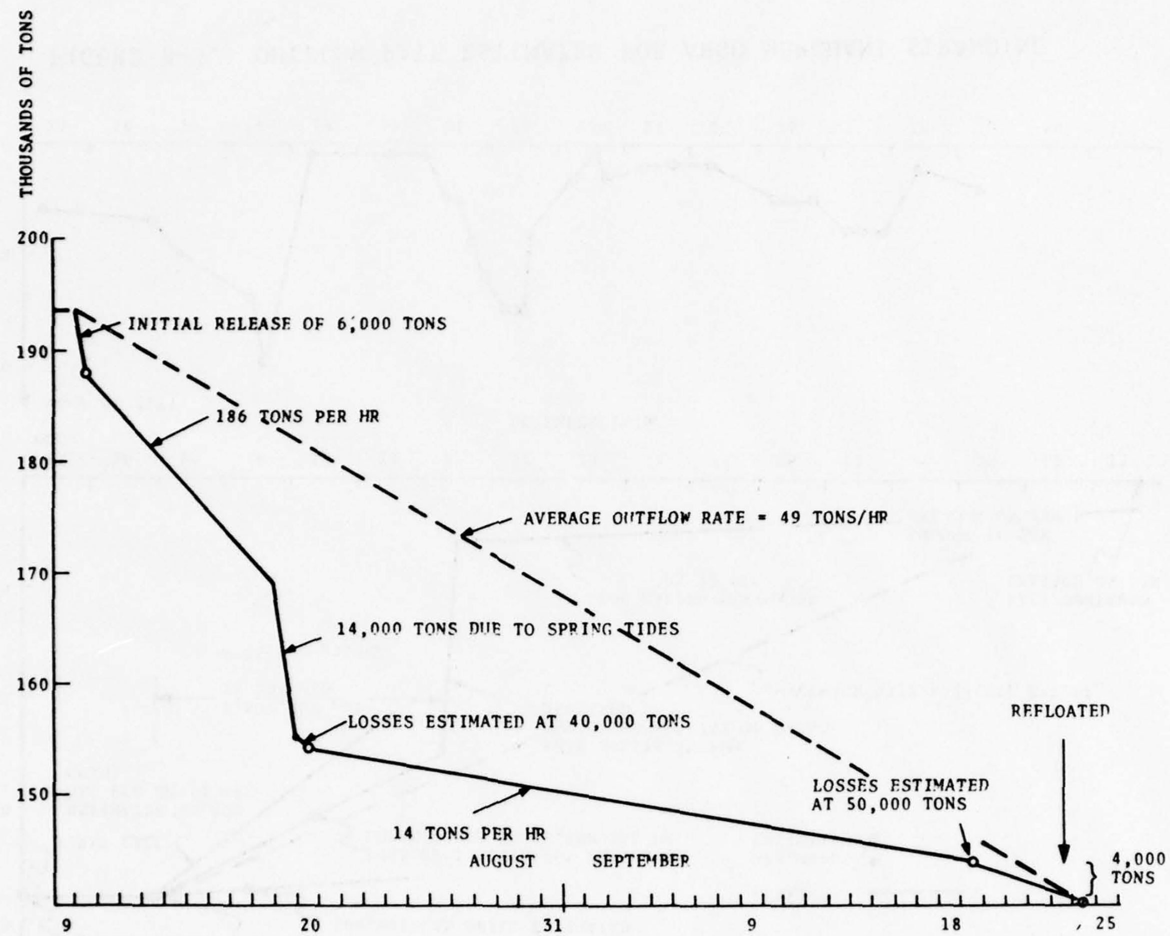

FIGURE B-2. OUTFLOW RATE ESTIMATES FOR METULA STRANDING

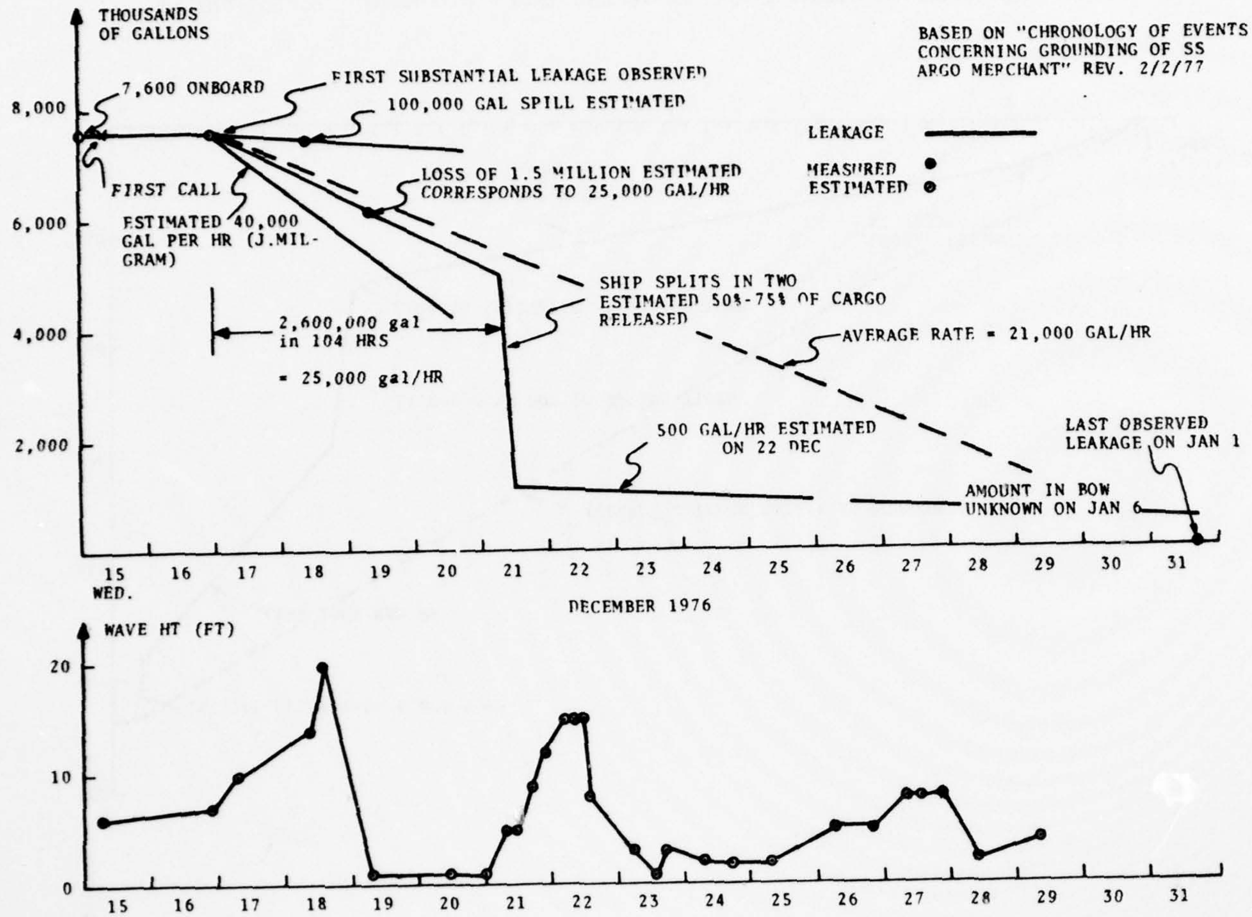

FIGURE B-3. OUTFLOW RATE ESTIMATES FOR ARGO MERCHANT STRANDING

March 20	:	"About 60,000 tons of oil leaking into the sea."
March 21	:	"Heavy seas have apparently opened another leak in a tank."
March 21	:	"Senior official of owners of AMOCO CADIZ said tonight the vessel had leaked some 170,000 tonnes of crude." Estimates that only 50,000 tons were still onboard. "more than 3 tanks have blown."
March 24	:	Aft part completely free of fore part, which is issuing more and more oil.
March 24	:	Estimates are that 30,000-35,000 tons are still inside.
March 26, 1300	:	French Navy opens hatches to release oil.
March 27	:	About 25,000 tons still on board.
March 29	:	Breaks into 3 parts; almost all oil released.
March 30	:	About 10,000 tons left.
March 30	:	Depth charges release remaining oil.
March 31	:	Divers report no oil remaining, only Bunker fuel left.

The time history of outflow for the AMOCO CADIZ is shown in Figure B-4. The initial rate of 4200 tons per hour is relatively uncertain because of the time at which the first estimate was made is uncertain. Because the vessel broke up early (1000 on March 17), it seems that the pattern seen in Figure B-4 is realistic., i.e., rapid discharge at first, followed by slower discharges. The average outflow rate of 600 tons per hour, shown by the dotted line in Figure B-4, is probably accurate to within 5%, the main uncertainty being the initial amount onboard.

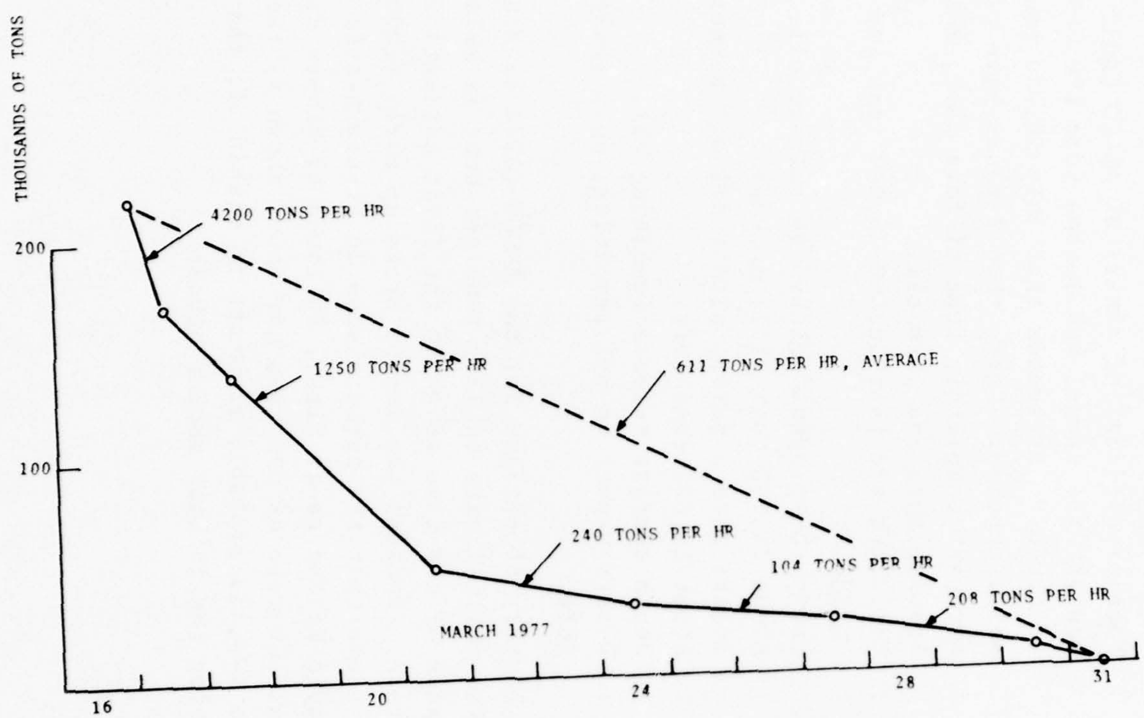

FIGURE B-4. *OUTFLOW RATE ESTIMATES FOR AMOCO CADIZ STRANDING*

REFERENCES FOR APPENDIX B

B-1 Canelas, L.D., and J.D. Monteiro, "Some Studies of an Oil Spillage Due to the Jacob Maersk Accident," Proceedings of the 1977 Oil Spill Conference, New Orleans LA, published by the American Petroleum Institute, 2101 L Street N.W., Washington, DC 22037

B-2 Gundlack, E.R., and M.O. Hayes, "The Urquiola Oil Spill: Case History and Discussion of Clean-Up and Control Methods," Marine Poll. Bull. 8(6): 132-136, 1977.

B-3 U.S. Coast Guard, "Report of the VLCC Metula Grounding, Pollution and Refloating in the Strait of Magellan in 1974," Submitted by R.I. Price, Rear Admiral, U.S. Coast Guard, Chief, Office of Marine and Environment and Systems, February 1975.

B-4 "Chronology of Events Concerning Groundings of SS ARGO MERCHANT," (Revised Feb. 2, 1977) U.S. Coast Guard internal notes.

APPENDIX C:

DISTRIBUTION OF U.S. COASTAL TANKER TRAFFIC IN 1985

Reference 4-16, Volume 3, gives U.S. petroleum imports and exports by trade route for the years 1973-2000. The U.S. exports in 1985 are small and will be ignored, and only the major import routes will be employed. The flows of crude/product in thousands of long tons for 1985, as extracted from Reference 4-16, are shown in Table C-1 along with the origins and destinations. The routes of Reference 4-16 are grouped by one of seven foreign origins and one of three domestic destinations. The major U.S. coastal passage area for each route is shown above the crude/product figure.

It should be noted that the petroleum movement projections of Reference 4-16 were made by assuming a 9.8% increase per year from 1975 through 1980, and a 1.1% increase from 1980-2000, in accordance with administrative goals for reduction of energy imports.

Next, one must add to Table C-1 the Canadian, Alaskan and U.S. Gulf-East Coast traffic, as is done in Table C-2.

Canadian Traffic. This has three components. The Caribbean-Canadian component was obtained by taking the 14,000,000 tons of Venezuelan-Canadian oil shown in Reference 4-1 for 1977 and dividing it evenly between crude and products, and then allowing an expansion of 3% per year from 1977 to 1985. The East Coast-Canada and the Gulf Coast-Canada figures for 1985 were taken directly from Reference 4-16, and include exports as well as imports.

Alaskan Traffic: The Trans-Alaska Pipeline is projected to put out 2.0 million BBL per calendar day at its peak in 1983-86. It was assumed that 80% of this amount is transported by vessel from Valdez to the West Coast and 10% to the East and Gulf Coasts each. Transshipment of refined and residual oil from the West Coast is allowed for by assigning 35% of the incoming crude as outbound product movement, 25% to the East Coast and 10% to the Gulf Coast. This is arrived at by allowing for 25% consumption on the West Coast and 40% shipment by pipeline to the Texas/Lousiana

TABLE C-1: CRUDE AND PRODUCT IMPORTS IN 1985 (1)
(THOUSANDS OF LONG TONS)

From / To	East Coast	Gulf Coast	West Coast
Ecuador	Mona Passage 216/110	Gulf of Mexico 315/14	Pacific Coast 5,398/109
Caribbean	PR-VI 25,580/83,760	1)Gulf of Mexico 2) PR-VI, Str. of Florida 33,965/6,687	Pacific Coast 2,766/2,452
N. Europe	N. Atlantic 554/4,859	Str. of Florida 539/185	Pacific Coast 16/15
Mediterranean	Atlantic 25,700/10,832	Str. of Florida 11,239/548	Pacific Coast 273/160
S.W. Pacific			Pacific Ocean 26,148/855
Persian Gulf	Atlantic* 14,660/325	Str. of Florida* 34,207/759	Pacific Ocean 28,426/464
W. Africa	Atlantic 45,759/867	Str. of Florida 23,233/65	

(1) Source: Reference 4-16

*The Reference gives only a single figure for East and Gulf Coasts. It has been assigned 70% to the Gulf and 30% to the East Coast.

TABLE C-2. CRUDE AND PRODUCT COASTAL FLOWS IN 1985 (THOUSANDS OF LONG TONS)

From	To: East Coast	Gulf Coast	West Coast	Canada (Atlantic)
Ecuador	216/110	315/14	5,398/109	
Caribbean	25,580*/83,760	33,965*/6,687	2,766/2,452	9,000/9,000
N. Europe	554/4,859	539/185	16/15	
Mediterranean	25,700/10,732	11,234/548	273/160	
S.W. Pacific			26,148/855	
Persian Gulf	14,660/325	34,207/760	28,426/464	
W. Africa	45,759/867	23,233/65		
Canada	472/3,250			
Alaska	10,000/00	10,000/00	80,000/00	
Gulf Coast	9,000/60,000			13/166
West Coast	0/20,000	0/8,000		
Total	121,948/163,830	103,489/8,256	163,027/39,055	9,013/9166

*Approximately 10,000 should be shifted to Persian Gulf origination if deepwater ports on U.S. East and Gulf Coasts are employed in 1985 to receive crude from the Persian Gulf that would otherwise be transshipped at P.R. and V.I. See text.

refineries and the rest as product out by vessel.

U.S. Gulf to U.S. East Coast Traffic: Reference 4-2 has estimated that 9 million tons of crude and 43 million tons of product moved eastward through the straits of Florida in 1974, based on ACOE and USGS data. This number would tend to decrease if domestic Gulf Coast production decreases, but increase if crude imports to the Gulf increase. In all likelihood it will increase with total demand and with shift of refining capability to the Gulf Coast. Hence product movement has been expanded by 3 1/2% per year from 1974 through 1985, in unison with anticipated world-wide demand increases (Reference 4-1 p. 243), while crude movement has been left at 9.0 million tons per year on the assumption that any additional refineries built in the East Coast would be balanced by increases in crude imports to the area directly via the Atlantic.

In interpreting Tables C-1 and C-2 it should be realized that the Maritime Administration projections included under a Caribbean origin much of the oil that reached the U.S. through trnashipment at Puerto Rico and the Virgin Islands. It is not known exactly how much oil is involved in these transhipments, but the MARAD report shows 15,64,000 tons of crude imported to Puerto Rico and the Virgin Islands in 1973, 13,683,000 tons in 1975 and projects 20,812,000 tons in 1985. This last figure is about midway between the amounts projected to be received by the Gulf Coast and by the East Coast from the Persian Gulf in 1985, and undoubtedly is more than Puerto Rico and the Virgin Islands can consume in a year. This 20,000,000 tons may go directly to the East and Gulf Coasts in 1985 if deepwater facilities are available to receive it.

APPENDIX D:

Reports on Marine Oil Spills

1967 - 1978

Prepared for:

U.S. DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
Transportation Systems Center
Cambridge Massachusetts 02142

Submitted by:

The Center for Short-Lived Phenomena, Inc.
138 Mt. Auburn Street
Cambridge Massachusetts 02138

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AMOCO CADIZ OIL SPILL
16 March 1978
off Portsall, France
(48°36'02"N, 04°45'09"W)

Event:

At 2226 LT on 16 March 1978, the 224,914-DWT tanker Amoco Cadiz ran aground in heavy seas off Portsall, France, on Men Goulven Rocks at 48°36'02"N, 04°45'09"W, after experiencing a flange failure in her steering hydraulic system. She incurred a 30-meter gash below the water line, just forward of the house. The rupture widened in the severe weather, and the aft storage tank began spilling its cargo of Arabian crude oil into the English Channel.

At 1045 LT on 16 March, while navigating in a storm through the Channel, the ship lost its rudder. At 1110 LT, the captain summoned the assistance of a German tug from Brest. By 1330 LT, the tug had the tanker in tow but made little progress toward port. At 1615 LT, the weather worsened and the towline broke. A second tow, established after nightfall, was only able to slow the tanker's drift, and the Amoco Cadiz grounded while still under tow.

By 2305 LT, French Navy helicopters arrived on-scene to airlift the 41 crew members to safety. The captain and first officer remained on board until dawn. At 0500 LT on 17 March, after hours of pounding by 6-meter seas in winds up to 80 km per hour, the tanker ruptured 3 tanks on its starboard, forward of the aft tank, and began to spill oil. By 18 March, the Amoco Cadiz had spilled 80,000 tons of oil. On 24 March, the stern section split off and swung around 180 degrees.

The Amoco Cadiz was built in 1974 in Cadiz, Spain, and had no history of previous spill incidents. Under Liberian registry, she was on lease to Royal Dutch Shell from a subsidiary of the Standard Oil Company (Indiana). She was carrying 216,000 tons of crude oil from Saudi Arabia and Iran to Le Havre, and then to Lyme, England, for transshipments to Rotterdam.

(AMOCO CADIZ OIL SPILL)

Cleanup:

Initial salvage efforts focused on offloading the cargo, but the heavy seas and spring tides precluded recovery. Seas of 5 meters and winds of up to 45 knots prevented salvage crews from navigating through the rocks surrounding the grounded tanker.

The French government quickly nationalized the cleanup effort and placed it under military jurisdiction. More than 7000 soldiers and 7000 civilians participated in the cleanup. Early efforts concentrated on protecting the most environmentally sensitive areas. On 17 March, workers began deploying booms along the river estuaries to protect the oyster beds. Commercial lobster pens were emptied, and the lobsters taken to other parts of France. Vacuum pumps were deployed to recover oil from inshore waters. The French government allowed the use of dispersants in waters greater than 50 meters deep and with currents moving offshore. A fleet of 30 ships treated the oil with the dispersants BP-1000 X and Corexit. They relied on absorbent polystyrene-based agents and on sinking agents such as chalk for inshore operations.

Prime Minister Raymond Barre immediately announced new regulations to guard against spills, including a ban on all transient tankers within 7 nautical miles of the French coast, increased surveillance of oil-bearing vessels, and a requirement that such ships keep officials informed as to their location at all times when in French waters. The government promised to pay $12 million in damages to fishermen and others. The tanker's owner, the Amoco International Company, said its insurance policy will cover cleanup costs and damage payments totalling up to $30 million.

(AMOCO CADIZ OIL SPILL)

Spill:

By 19 March, 10 cm of oil covered the harbor of Portsall, while oil fumes spread over coastal regions. After a week of heavy seas, the tanker had spilled over 200,000 tons. The slick was then 6.5 km wide and 201 km long. It stretched from Portsall to the Ile du Brehat and the port of Paimpol along the Britanny coast. The French military bombed the tanker from 29 to 31 March to release the remaining cargo.

According to local authorities, the spill has caused severe damage to the fishing grounds and commercial seaweed beds. The authorities expect that the seaweed beds, which provide 90% of the French commercial harvest, will take several years to recover and that the fishing industry will take at least a year. A 50% decrease in tourist business is already evident in Britanny.

TORREY CANYON OIL SPILL
18 March 1967
near Scilly Islands, England
(50°00'N, 06°05'W)

Event:

At 0850 LT on 18 March 1967, the Liberian-registered tanker Torrey Canyon ran aground on Pollard Rock of the Seven Stones, approximately 20 km west of Land's End, England, and 10 km east-northeast of the Scilly Islands. The previous night, the vessel had gone off its planned course west of the islands. The tanker was travelling at 15.75 knots. The grounding reportedly tore 6 of the tanker's 18 tanks and damaged several others.

The Torrey Canyon was built in Newport News, Virginia, in 1959 and was extended from 66,000 DWT to 120,000 DWT in Japan in 1964. She was owned by a subsidiary of the lessee, Union Oil Company. She was under time-charter to British Petroleum to carry a cargo of 119,193 tons of Kuwaiti crude oil from Mina al Ahmadi in the Persian Gulf to Milford Haven in Wales.

Cleanup:

The British government assigned overall control of the cleanup operation to the Under Secretariat of State (Royal Navy). Offloading the oil from the tanker was not attempted since it was impossible to maneuver receiving vessels into the area. Some of the escaping oil burned, after the British military bombed the Torrey Canyon from 28 to 30 March. Booms were deployed but proved ineffective. As a result, the British concentrated their cleanup strategy on dispersants. Two naval vessels began applying dispersants on 18 March, and were later joined by other ships. Within 3 days, 15,000 gallons of detergent were applied. Detergents and steam-cleaning were used to clean the shore.

While the British used dispersants near the Channel Islands, the French applied chalk powder to sink oil in the Bay of Biscay. Sea booms of jute fiber and plastic were deployed to keep the oil out of Roscoff harbor in Britanny. The British government reimbursed local authorities for more than 75% of the cleanup costs and provided troops at no local expense to help during the cleanup.

(TORREY CANYON OIL SPILL)

The Navy's threat to seize and impound the Torrey Canyon's sister ship, the Lake Palourde, enforced demands that the tanker's owner, in turn, reimburse the British government.

Spill:

By dusk of 18 March, northerly winds had carried a narrow slick over 13 km long to the south. By the next day, an estimated 20,000 tons had leaked from the tanker, with another 10,000 tons leaking out on 20 March. The slick was then more than 30 km long. The winds shifted to the west, driving oil into the English Channel. The westerly winds continued until 24 March, and on 25 March the morning tide brought the first oil onshore in thick layers. On 26 March, when the tanker broke in two, more than 40,000 tons of oil escaped, threatening the British coast and then the Britanny coast, before moving into the Bay of Biscay. After the bombing, oil seeped out in small amounts. In late April, the Torrey Canyon slipped off Pollard Rock and sank. Officials estimated that the sunken tanker contained no significant amounts of oil.

The spilled oil contaminated about 140 km of British coast from Trevose Head to Lizard Point, 150 km of French coast from Roscoff to Paimpol, 40 km of Britanny's west coast, and 25 km along the Channel Island of Guernsey. The oil caused extensive mortalities among seabird populations. The oil and especially the detergents were extremely toxic to marine life, especially planktonic organisms.

TRANSHURON OIL SPILL
26 September 1974
Kiltan Island
(11°30'N, 73°01'E)

Event:

At 1630 LT on 26 September 1974, the U.S. tanker Transhuron ran aground on Kiltan Island, an atoll in the Arabian Sea 300 km from the coast of India. The accident occurred when the tanker went out of control due to a fire hazard in the boiler room. The tanker's crew abandoned ship about 400 meters from the island. Upon grounding, several tanks ruptured, and approximately 5000 tons of furnace oil spilled into the sea. Of the remainder of the 18,000-ton cargo, 12,700 tons were removed from the Transhuron on 3 December. The 19,650-DWT vessel, under charter to the U.S. Navy from Hudson Waterways Corp., was en route from Bahrain to the Philippines.

Cleanup:

Several research institutions, with support from the Indian Navy, took measures to prevent further spillage from the grounded tanker. These efforts culminated in the offloading on 3 December. Navy officials made several aerial surveys to track the shoreward movement of the oil. No efforts were undertaken to cleanup the coast of Kiltan Island.

Spill:

The spill impacted all of Kiltan Island, except for the beaches on the eastern shore. Oil that entered the atoll's lagoon was washed ashore, and thick oil patches were reported on the beaches there. The volatile components evaporated, while the remainder seeped into the coarse sand up to a depth of 3 to 10 cm. The oil caused heavy contamination along the rocky intertidal area along the southern shore.

During the first week after the grounding, local flora and fauna suffered widespread mortalities. Dead plankton and seaweed were reported floating in thick layers in the lagoon, along with

(TRANSHURON OIL SPILL)

dead fish, lobsters, crabs, and other species. Some of them washed onto the beach a few days later. The spill adversely impacted the hermatypic corals, which build and protect the atoll.

ENNERDALE OIL SPILL
1 June 1970
Port Victoria, Mahe, Seychelles Islands
(04°30'S, 55°30'E)

Event:

On 1 June 1970, the British Royal Fleet auxiliary tanker Ennerdale struck a pinnacle of granite while leaving Port Victoria, Mahe, in the Seychelles Islands, and badly ruptured its hull on the starboard side. The tanker sank rapidly in 40 meters of water, with the bow remaining slightly above water for some time. The Ennerdale was carrying 41,500 tons of oil, and was en route to refuel the British Navy frigate Andromeda at sea.

Cleanup:

A tanker was retained in ballast at Bahrain pending a decision to offload oil from the Ennerdale, but adverse weather prevented the transshipping of the cargo, as well as a survey of underwater damage. The British Ministry of Defense directed the cleanup, which included attempts to contain the slick with a boom and to spray it with dispersants.

Spill:

Due to favorable winds and water currents, the oil did not cause significant contamination along the coast. On 19 June, there was still a large slick of diesel oil and aircraft fuel on the water. Oil continued to leak through the sunken tanker's air vents. It is not known how much cargo spilled. The major concern was that the slick would cause an extensive mortality among the Seychelles seabird population, which includes many endangered species.

NAPIER OIL SPILL
8 June 1973
Island of Guamblin, Chile
(44°50'S, 75°00'W)

Event:

On 8 June 1973, the 35,000-DWT tanker Napier ran aground on the Island of Guamblin, 35 km off the Chonos Archipelago in Chile. The ship's radar was not functioning when the ship struck the island, which is 330 km south of Puerto Montt, the nearest port. After a severe storm on 14 June, the tanker reportedly sank. The Napier was carrying an unspecified quantity of light Bolivian crude.

Cleanup:

Because of the remoteness of the Island of Guamblin, the Chilean government decided that the most effective way to deal with the spilled oil was to burn it. On 12 June, the Chilean Air Force dropped incendiary bombs on the slick, igniting the tanker's stern. The next day, airplane pilots observed that the ship was burning.

Spill:

It was not known how much oil spilled, burned, or remained in the Napier. There was no reported fouling of any shorelines or coastal waters. The spill raised concern about the fate of a mussel farm located in the interior of the Chonos Archipelago. There was, however, no reported damage to the farm.

ESSO ESSEN OIL SPILL
29 April 1968
off the Peninsula Coast, South Africa
(34°18'30"S, 18°20'00"E)

Event:

At 0640 LT on 29 April 1968, the West German-registered tanker Esso Essen hit a submerged object at a speed of 18 knots while headed almost due northwest 5 km off South Africa's Peninsula Coast, and ruptured 8 tanks. The weather was good with fair visibility, almost no wind, and a moderate swell. The tanker proceeded under her own power in a northwesterly direction to 20 km west of Duiker Point and then northeastward towards Table Bay. She waited more than 9 km west off Green Point Lighthouse for clearance to enter the harbor of Cape Town.

The Port Captain at Cape Town refused clearance and ordered the ship to sea. The Esso Essen departed the same day to drift roughly 130 km offshore, where the Port Captain inspected the damaged tanker. An estimated 15,000 tons of oil were lost, including about 4000 spilled off the Peninsula Coast. A slick 1 to 2 km wide and more than 30 km long was reported at a distance from the coast varying from 3 to 25 km. The 50,897-DWT Esso Essen, built in 1960, was bound for West Germany with a load of heavy Arabian oil from the Persian Gulf.

Cleanup:

Aerial surveys were initiated over most of the Peninsula Coast shoreline and waters at roughly the time that slicks were first observed. Machinery such as "slick-licker" belts was not available for removing oil from the ocean. The cleanup efforts concentrated on spraying dispersants, flown to Cape Town from the United States. The South African Minister of Industries approved the use of Esso Corexit as a dispersant, after finding that Corexit was generally less toxic than those chemicals used during the Torrey Canyon cleanup. In total, an estimated 80 to 90% of the 4000 tons of oil spilled off the Peninsula Coast washed onto beaches.

(ESSO ESSEN OIL SPILL)

Spill:

The slick, first seen extending from Scarborough to Clifton, was carried southeastward by northwesterly winds. It followed the coast until, by 1 May, the northern end had cleared Duiker Point. The first landfall was on the night of 30 April from Scarborough to a point 25 km south. On 2 May, Chapman's Bay, just north of Scarborough, was contaminated. On 3 May, oil reached Cape Point and began moving across the mouth of False Bay. On 4 and 5 May, the slick impacted Cape Hangklip and Pringle Bay, on the other side of False Bay. The oil had a frothy appearance, indicating emulsification. Thick oil was deposited above the kelp, which had been washed up by heavy seas. Beach cores showed little penetration into the sand.

The oil killed millions of sand hoppers, but that seemed to be the only massive mortality. Periwinkles, limpets, and anemones suffered appreciable mortalities. Many pelagic birds were seen oiled, but only a few gannets and cormorants were found dead. Scientists sampled the water and found no probable adverse effects to phytoplankton but moderate to high mortalities among zooplankton. By 6 May, the pollution along the Atlantic coast had diminished, except for some oil-covered rocks in Chapman's Bay.

BRAZILIAN MARINA OIL SPILL
9 January 1978
Sao Sebastiao, Brazil
(23°48'S, 45°43'W)

Event:

Late at night on 9 January 1978, the Liberian-registered tanker Brazilian Marina struck a rock while entering a dredge channel near Sao Sebastiao, Brazil, and ruptured 2 port wing tanks with a hole 40 meters long and 1 meter wide. About 15,000 tons of crude oil spilled. The vessel, under lease to Petrobras, was entering Sao Sebastiao harbor while en route from Kuwait to the Petrobras refining facility.

Cleanup:

Under the coordination of the Sao Paulo State Environmental Control Agency, local municipalities undertook the cleanup effort, which lasted for several weeks. A 5-man USCG/EPA team provided advice to the Brazilian officials and conducted surveys of environmental damages. Cleanup efforts were largely manual, involving rakes, shovels, and straw. Officials reported particular success with Japanese pine straw. Limited use was made of vacuum machinery. The tanker's owners paid punitive fines totalling $137,000. On 30 January, they agreed to pay damages and cleanup costs not exceeding $500,000. On 31 January, when the insurance company assured payment, the ship was allowed to sail.

Spill:

On 10 January, the spilled oil was reportedly moving along the shoreline from Sao Paulo north towards the state of Rio de Janeiro. A layer of oil, 0.5 to 2.5 cm thick, impacted the beaches in the state of Sao Paulo, and oil slicks along the coast threatened further contamination for several weeks. Heavy rain helped disperse the slicks. On 17 January, they were observed 40 km south of Rio de Janeiro.

(BRAZILIAN MARINA OIL SPILL)

The USCG/EPA team found no serious long-term danger to marine life. Local officials estimated that short-term mortalities of sardines, shrimp, and mussels will ruin the season's harvest. Few dead fish or oiled birds were found, although it was estimated that thousands had been contaminated.

ARROW OIL SPILL
4 February 1970
Chedabucto Bay, Nova Scotia, Canada
(45°27'57"N, 67°06'24"W)

Event:

At 0934 AST on 4 February 1970, the Liberian-registered tanker Arrow, carrying 3.8 million gallons of Bunker C fuel oil, ran aground on Cerberus Rock in Chedabucto Bay, Nova Scotia, in high seas and winds. Immediately upon grounding, the bottoms of the forward oil tanks ruptured, and oil began to spill into the bay. On 8 February, the tanker split in two, leaving the bow section stuck firmly on the rocks, with 6 out of its 9 tanks ruptured. The stern section, with 950,000 gallons of oil, sank on 12 February before it could be towed and sunk in deep water off the continental shelf.

By 14 February, an estimated 1.5 million gallons had spilled, making the Arrow spill the largest in Canadian history, and another 1.3 million gallons had been salvaged. Extreme cold prevented further salvage. Plans to steam-heat the oil were not carried out because the tanker's boilers were inactive. The wreck continued to leak oil, including a spill of 30,000 gallons on the night of 24 March. The 18,000-ton Arrow, owned by Sunstone Maritime Ltd., was on charter to the Imperial Oil Company. She was carrying her Venezuelan cargo to the Nova Scotia Pulp Ltd. mill at Point Tupper, Nova Scotia.

Cleanup:

A fine mesh seine-net boom was constructed about 600 meters long and 9 meters deep, with flotation about 30 to 60 cm above the surface. In combination with peat moss absorbent, this boom was effective in containing the spilled Bunker C oil in sheltered areas, but rough seas precluded the containment of oil on the open ocean. Oleophilic "slick-lickers" were deployed with success in recovering oil in sheltered areas. Where recovery was impossible, burning was attempted. Magnesium flares and glass beads were dropped on the spill to both generate and retain

enough heat for combustion. By 9 February, the cleanup crews had still not decided on the best way to ignite the oil, and a large amount of the oil had emulsified, reducing the probability that it would burn. Where the oil had not already emulsified beyond flammability, it was difficult to sustain combustion temperature. The Canadian Ministry of Transport, responsible for cleanup operations, reported that no dispersants or sinking agents had been used on the slick, although Imperial Oil Co. had reportedly chartered 2 planes to spray dispersants. Due to low temperatures and poor penetration into the slick, the dispersants were largely ineffective. The Ministry of Transport planned to hold both Sunstone Maritime and Imperial Oil liable for cleanup costs, estimated at $3 million.

Spill:

During the first day after the grounding, the slick was carried north and east by 50-knot winds blowing from the south. In the first several hours, a falling tide helped initiate the seaward movement of the slick. On the second day, the wind changed and blew largely from the north for 3 to 4 days. The slick extended for 6.5 km on the open ocean, with smaller slicks remaining inside Cape Auget. After water cushions had developed in many tanks, precluding further major spillage, oil leaked only sporadically from the bow. Although no divers inspected the sunken stern, officials do not believe it leaked any oil.

In total, the spilled oil impacted 320 km of Chedabucto Bay coastline, with the larger portion on the southern shore. A rock dam constructed from Ile Madame to Cape Breton Island to combat the spill prevented contamination of the sound between the islands. On 27 February, oil washed ashore on the northern coast of Sable Island, some 200 km southeast of the Arrow. Chemical analysis traced the oil to the spilled Bunker C.

(ARROW OIL SPILL)

As a result of the spill, 10 gray seals were reported dead, with others heavily oiled and disoriented. The most heavily impacted fauna were sea birds. An estimated 2300 died in Chedabucto Bay, another 5000 dead washed onto Sable Island, and many more dead birds were probably carried south of Sable Island into the open ocean.

BORAG OIL SPILL
7 February 1977
Keelung, Taiwan
(25°12'10"N, 121°44'30"E)

Event:

At 1145 LT on 7 February 1977, the Kuwaiti-registered tanker Borag hit a reef and ran aground in the East China Sea, 3 km north of Keelung, Taiwan. The grounding ruptured 2 of the vessel's 30 tanks; other tanks leaked later. An estimated 4000 tons of the 33,068-ton cargo of crude oil spilled into the sea. A Keelung pilot was on the Borag at the time of the grounding. Of the 37 people on board, 19 were taken ashore immediately, and the others were rescued by 10 February.

On the first day, no attempt was made to refloat the tanker since the pilot feared a break-up. The next day, 3 tugs and 2 patrol vessels failed to free the Borag from the reef. The bow sank during the first 4 days, and the buoyant stern finally sank on 15 February. Strong winds and high waves hampered efforts to remove oil prior to the sinking. On 8 March, a dredge struck the submerged tanker and sank. The 35,351-DWT Borag was en route from Kuwait to a Shenao, Taiwan refinery when the grounding occurred. The cargo was owned by the Chinese Petroleum Corporation and the vessel by Hamoor Tanker Corporation.

Cleanup:

The Taiwanese Navy supervised the efforts to contain and cleanup the spilled oil, and received assistance from the Keelung Harbor Bureau, other government agencies, and industry experts. Industrial and utility plants using seawater coolant systems shut down their operations. On 8 February, the Harbor Bureau prepared a sea boom to fend the spill away from the coast. Aside from attempts to offload the cargo from the sunken ship, there were no reported efforts to recover the oil. Large amounts of dispersants were used to keep the slick out of Keelung harbor. No attempt was made to disperse the entire slick.

(BORAG OIL SPILL)

Spill:

On the first day, southwesterly gusts blew slicks away from the coast. By 11 February, the wind had shifted to a prevailing northeasterly direction, blowing oil onshore in amounts ranging from small patches to thick layers. Yeh-Lin harbor and adjacent resort areas were heavily polluted, with oil collecting in coves and behind breakwaters. Keelung harbor received progressively larger amounts of oil from 11 to 24 February, by which time fishing boats could no longer cross the 50-cm-thick rafts of oil. Smoking and welding were strictly forbidden in and around the harbor. The slicks remained offshore for almost two weeks, threatening the coolant intakes. The oil curtailed fishing off a 60-km stretch of coastline, and killed almost all the young eel in the spill area. Potential costs to the fishing industry were estimated at millions of dollars.

PACIFIC GLORY OIL SPILL
23 October 1970
off Isle of Wight, England
(01°05'W, 50°40'N)

Event:

On 23 October 1970, the tankers Pacific Glory and Allegro collided in the English Channel while headed towards Rotterdam and Fawley, England, respectively, and the Pacific Glory immediately caught on fire. Thirteen of the Pacific Glory's crew were killed in the collision and fire. The Allegro sustained minor damage and proceeded to Fawley to unload its cargo. After the collision, the Pacific Glory was grounded in 5 meters of water 5 km off the Isle of Wight. Two weeks and several storms later, 20,000 tons of the Pacific Glory cargo were offloaded to another tanker. Then the grounded tanker was refloated and repaired, and 14,000 tons were loaded back onto the tanker. On 17 November, the Pacific Glory arrived in Rotterdam with 64,000 tons of her original 77,000-ton cargo. The 6000 tons that had been offloaded were also shipped to Rotterdam. In total, almost 7000 tons of oil spilled from the Pacific Glory.

Cleanup:

The British Admiralty coordinated the initial efforts to cleanup the oil. The Navy employed two Dutch government-owned ships: one specially equipped to apply dispersants and the other a dredger converted to spray chemically treated sand for sinking oil slicks. Shell Marine International, the Pacific Glory's charterer, volunteered its service during the cleanup. Since the collision was outside British territorial waters, C.Y. Tung of Hong Kong, the owner, contracted with a Dutch salvage firm on 27 October to refloat the tanker and relieve the Admiralty of the cleanup operation.

Channel tugs moving at full speed sprayed dispersants on the slicks. Wooden frames towed behind the tugs agitated the water, mixing together the oil and dispersant and thereby increasing the dispersant's effectiveness. Officials described

the dispersants and sinking agents as successful in preventing shoreline pollution. Boats with dispersants on board accompanied the *Pacific Glory* to Rotterdam.

C.Y. Tung and Shell International Petroleum Company Ltd. were both party to TOVALOP, which substantially reimbursed the British government for its efforts.

Spill:

Most of the oil which spilled from the *Pacific Glory* was diesel and fuel oil. Some burned on the water, while the rest was either dispersed or sunk before wind or current could carry it far. There was no reported pollution of the coastline, but for 3 weeks, until the damaged tanker reached Rotterdam, officials feared that she would rupture again and spill her cargo into the Channel.

OCEAN EAGLE OIL SPILL
3 March 1968
San Juan, Puerto Rico
(18°30'N, 66°10'W)

Event:

At 0937 LT on 3 March 1968, the 18,524-DWT, Liberian-registered tanker Ocean Eagle ran aground in heavy seas while heading into San Juan Harbor, Puerto Rico. The captain attempted to head the tanker seaward by pivoting her on the grounded mid-section. During this procedure, the 15-year-old Ocean Eagle split in half. The tanker was carrying 5.7 million gallons of crude oil from Venezuela to San Juan. The stern half, which remained intact, retained its oil, which was eventually pumped out. The spillage from the bow was estimated at 2 million gallons: 1 million by 7 March, and 1 million by 19 March.

Cleanup:

The USCG and Navy undertook a lead role in the cleanup, with the tanker owners paying for the cleanup costs. On 1 April, the bow and stern sections reportedly contained no oil, and the Army towed them to deep water to sink them.

Where oil threatened shores and beaches, cleanup crews initially used detergents. Marine scientists objected to the potentially adverse ecological effects of the detergents, and the cleanup crews switched to Ektopearl, a non-toxic, porous substance that absorbs oil and floats. The damage to the marine environment appeared slight.

Spill:

Oil spread east and west, covering a 16-km stretch and impacting public, private, and military beaches. Currents carried the oil onshore, where patches washed within 100 meters of resort hotels. By 19 March, favorable currents had carried most of the oil out to sea, and public beaches were reopened. Some oil remained in San Juan Harbor, with accumulations at La Perla and slum areas.

(OCEAN EAGLE OIL SPILL)

As of 19 March, 500 pelicans had been pulled from the oil, cleaned, and taken to rehabilitation centers. Some waders and plovers were found, but in general the bird populations were sparse. A few octopi were found dead.

VENOIL/VENPET COLLISION AND OIL SPILL
16 December 1977
near Port Elizabeth, South Africa
(34°25'S, 24°05'E)

Event:

At 0938 LT on 16 December 1977, the Liberian-registered sister tankers Venoil and Venpet collided and caught fire less than 40 km off the South African coastline near Port Elizabeth. The motor vessel Clan Menzies successfully evacuated the entire 44-man crew of the Venpet. When the crew members from the Venoil abandoned ship, many lept into the shark-infested waters around the tanker; 38 men were rescued, and 2 were reported missing. After the collision, the ships separated from each other and both drifted in a southeasterly direction until they were taken under tow on 17 December.

The Venoil and Venpet are both owned by the Venoil Company. The Venoil, laden with 307,045 tons of Iranian heavy oil, was en route from Kharg Island in the Persian Gulf to Point Tupper, Nova Scotia; the Venpet was making a return voyage in ballast along the same route, with only cargo residues and bunker fuel on board.

Cleanup:

On 16 December, 5 coastal anti-pollution vessels arrived on-scene, along with rescue boats and fire-fighting salvage tugs. The fire hampered efforts to approach the damaged tankers and offload the cargo, but the heat increased the rate of emulsification and evaporation.

As soon as the fire was extinguished on 17 December, the anti-pollution vessels started to apply dispersants to the slick. Conservation organizations were reportedly pouring dispersants on the slick with little effect. From 5 to 7 January 1978, the Venoil's cargo was safely offloaded to another tanker, the Litiopa. When the wind and swells increased, the offloading hoses were disconnected, and the vessels were kept headed into the wind by tugs.

(VENOIL/VENPET COLLISION AND OIL SPILL)

Spill:

On 17 December, press reports said that the Venoil was trailing a 100-km slick and the Venpet a small slick of undetermined size. Some of the spilled oil burned on the water near the tankers. For more than a week, the slick threatened South African resort beaches on the country's southeastern shore. On 29 December, gusting onshore winds drove a slick 11 meters wide and 14 km long onto the beaches between Kwysna and Mossel Bay, while other larger slicks remained offshore and to the south. Oil washed up near the mouth of the Gouritz River, accumulating in deposits up to 5 cm thick. On 30 December, the main slick was less than 2 km from shore. As the day progressed, southeasterly winds gusting up to 40 knots drove much of the slick onshore, and the next day, onshore winds carried oil onto Tougaart Beach north of Durban. In total, the oil impacted 100 km of beaches. The spill destroyed prawn beds, although its full environmental effect was largely unreported.

TSESIS OIL SPILL
26 October 1977
Sodetalje, Sweden
(58°49'42"N, 17°43'48"E)

Event:

At 1000 LT on 26 October 1977, the 177-meter Soviet tanker Tsesis struck an uncharted, submerged rock while navigating through a narrow 480-meter-wide channel into Sodetalje, near Stockholm, Sweden. A Swedish pilot was on board when the vessel hit the rock at the edge of the channel. Navigational charts indicated a channel depth of 9.75 meters, although subsequent soundings showed a rock 8.23 meters below the water surface.

The grounding ruptured 8 cargo tanks, and the Tsesis began to spill oil immediately. An estimated 1600 tons of oil were lost. Initially, the Soviet captain of the Tsesis wanted to off-load his cargo into another Soviet tanker. When that tanker arrived, its tanks proved unfit to receive the oil. The cargo was offloaded into Swedish ships. The Tsesis was pulled free on 31 October and anchored near the grounding site. On 4 November, the Tsesis proceeded slowly to a Stockholm shipyard under her own power for repairs.

Cleanup:

Swedish authorities responded quickly to the spill. The Swedish Coast Guard assumed responsibility for the cleanup operations, and the Air Force undertook helicopter overflights. Booms were deployed around the tanker, and "slick-licker" belts and suction equipment were used to recover the oil. While the weather was calm, recovery proceeded with fair success.

On 29 October and again on 1 November, strong winds and rough seas rendered the booms, skimmers, and suction equipment ineffective. Local fire brigades helped cleanup the shore. On 31 October, the Soviet captain said that Sweden should pay the cleanup costs since a Swedish pilot was aboard. Swedish law, however, requires the shipowner to pay, even when a Swedish pilot is on duty.

(TSESIS OIL SPILL)

Spill:

At the time of the grounding, the weather was relatively calm. Shortly thereafter, a westerly wind with gusts up to almost 25 knots began to alternate with a calm, and the oil started moving towards the eastern shore of the channel. Later, the wind shifted from the west to the south, and the oil began to drift north. By 28 October, a water cushion had formed inside the ruptured tanks, stopping further leakage. On 30 October, oil had washed up along about 3 km of coastline on islands in the channel to Sodetalje. The next day, the spill, covering an estimated 13.7 sq km, had impacted as many as 10 islands. Most of the oiled areas were rocky cliffs, but some ground areas were affected.

JULIANA OIL SPILL
30 November 1971
Niigata, Honshu, Japan
(38°00'N, 138°40'E)

Event:

On 30 November 1971 at 1650 LT, the Liberian-registered tanker Juliana dragged her anchor in rough weather, while waiting for a pilot to guide her into Niigata harbor on the west coast of Honshu, Japan. Drifting aground just outside the harbor, the Juliana split in two, the bow coming to rest 300 meters and the stern 100 meters from shore, with a distance of 3000 meters separating the sections. All 47 crew members were rescued. The Juliana was carrying 18,000 tons of crude oil from the Persian Gulf to Niigata. In total, an estimated 4000 tons of oil spilled, and the remainder was offloaded to other boats.

Cleanup:

In Japan, at the time of the grounding, there was only enough dispersant to treat 5000 tons of oil. By 2 December, nearly 600,000 liters of dispersant had arrived in Niigata, and 60,000 liters had already been applied to the slick. By 3 December, 2 helicopters and 6 fire engines joined the 12 patrol boats applying dispersants.

Oil companies, on the recommendation of the Japanese government, placed a floating plastic boom around the slick. Initially high winds rendered the boom ineffective. On 2 December, winds subsided, and the boom was able to contain the slick. Straw mats were used to absorb the oil.

On 5 December, the tanker's sections were secured with anchors at sea and ropes onshore. A plan to place a siphon pump inside the stern section was abandoned, because rough weather made it impossible for salvage tugs and a small tanker to approach the wreck. As an alternative, a 10-cm water hose with PVC flotation collars was laid from the ship along the shore to the harbor, but bad weather also hampered this plan.

(JULIANA OIL SPILL)

Spill:

One day after the grounding, an oil slick, 20 km long and 4 km wide, had formed. Ocean currents and winds carried a large part of the slick to sea, but some oil and oil-soaked flotsom reached the shore. Officials expressed concern about the impact of the oil slick on the rich fishing grounds in the Sea of Japan. On 7 December, helicopters reported a thin oil film extending 8 km from Niigata north to the mouth of the Agano River.

Oil from the Juliana killed all the fish in the offshore stationary nets that local fishermen had set before the grounding. The nets were set on the sea bottom 1810 meters off Tayuhama beach in Niigata. The haul was abnormally small, and no octopi were reported.

M/V SAINT PETER OIL SPILL
4 February 1976
off coast of Colombia
(01°30'N, 79°34'W)

Event:

On 4 February 1976, a fire broke out in the engine room of the 34,175-DWT Liberian-registered M/V Saint Peter while the vessel was sailing 45 km west of the Ecuadorian coast. Due to the danger of explosions, the 34-man crew abandoned ship. At the time, the tanker was bound for Peru with a cargo of 243,442 barrels of crude oil, and 6000 to 7000 barrels of bunker fuel oil. On 6 February, at 01°35'N, 79°13'W, oil was observed bubbling to the surface and spreading out into a large slick. It was assumed that the ship had drifted and then sunk near this location in more than 700 meters of water.

Cleanup:

The USCG undertook overflight surveys and predicted that sea currents and wind would disperse much of the light oil before it reached the shore. As of 19 February, no cleanup operations had been initiated. Officers from the USCG and the Canadian Coast Guard developed a cleanup plan for Colombia in case of pollution. The Ecuadorian government also asked the USCG for advice.

Spill:

On 13 February, 3 separate oil ribbons, covering a total area of approximately 124 sq km, were observed drifting toward shore. The longest ribbon was 24 km long and 15 meters wide and was still being fed by oil bubbling to the surface. As of 13 February, the slicks were about 24 km from shore. The slick characteristics indicated that the discharge had been cargo rather than fuel oil.

On 17 February, oil slicks of medium to heavy thickness, covering approximately 52 sq km, were observed 5 km from the Colombian coast. The slicks, which had spread southward into Ecuadorian waters and had streaks extending into Tumaco Harbor, reached beaches and mangrove swamps in Tumaco. There was apprehension that local tuna and shrimp industries would be adversely impacted by continuing seepage.

IRENE'S CHALLENGE OIL SPILL
18 January 1977
North Pacific Ocean
(26°53'N, 173°52'W)

Event:

On 18 January 1977, the Liberian-registered tanker Irene's Challenge broke in two in the North Pacific Ocean, about 350 km east-southeast of the Midway Islands and over 1600 km west-northwest of Honolulu. On 17 January at 1700 Honolulu time, the tanker issued an SOS, which was relayed to the USCG by the Universal Conveyor, a ship in the area. The merchant ship Pacific Arrow rescued 28 of the crew of 31 and took them to Japan on 18 January. The other 3 reportedly stayed behind to prevent Irene's Challenge from sinking. They were missing and presumed dead.

The USCG dispatched 2 cutters and an airborne strike team to the scene. The two halves of the tanker remained afloat for several days, drifting southeastward 40 km from each other. They sank after 21 January. The 21,090-GWT Irene's Challenge, owned by Tsakos Shipping and Trading Co. of Piraeus, Greece, was en route from Japan to Venezuela with 3.15 million gallons of light Arabian crude oil in her 4.2-million-gallon capacity tanks.

Cleanup:

The USCG strike team arrived at 1145 GMT on 19 January to determine the feasibility of containing and recovering the spilled oil. High capacity A.D.A.P.T.S. pumps were ready for deployment from aircraft.

Spills:

An undetermined amount of the cargo spilled into the sea. The slick covered more than 400 sq km by 19 January, and was heading in an easterly direction. Seas in the area were about 2 to 3 meters with a wind at 10 to 15 knots.

HAWAIIAN PATRIOT OIL SPILL
24 February 1977
North Pacific Ocean
(21°10'N, 164°00'W)

Event:

At 1040 Honolulu time on 24 February 1977, the Liberian-registered tanker Hawaiian Patriot caught fire and exploded in the North Pacific Ocean more than 600 km west of Honolulu. A pilot in a reconnaissance plane reported seeing smoke amidships, as the crew began to leap into the sea. The merchant ship Philippine Bataan rescued 38 of the 39 crewmen. One was found dead.

The Hawaiian Patriot burned fiercely for several hours and eventually sank. The 258-meter, 51,576-GWT tanker was owned by Indo-Pacific Carriers and was under lease to Groton Pacific Carriers. She was carrying 28.2 million gallons of light Indonesian crude oil to Honolulu.

Cleanup:

Although the USCG monitored the spill, no cleanup operations were undertaken. Some of the spilled oil burned with the ship.

Spill:

The oil started leaking from the No. 2 port and stern cargo holds. It is unclear whether there was a crack or an entire missing hull plate. The spill was reported at 1639 Honolulu time on 23 February. By the time of the explosion, an estimated 5.25 million gallons of the cargo had leaked into the sea, forming a slick almost 85 km long. The rest of the cargo sank with the ship.

On 28 February, the slick was about 750 km west of Honolulu and reportedly 23 km wide and 70 km long, with the heaviest concentration of oil at the western end. On 7 March, the slick, located more than 780 km west of Honolulu, had evaporated and emulsified until it was only 32 km long and 3 km wide.

APPENDIX E:
DEBARKATION PORTS

The debarkation point is usually selected by the OSC soon after he determines that pollution control equipment must be brought to the scene. He usually selects the nearest port that can handle the required equipment. It may be more convenient to stage different equipment at different points, so there may be several debarkation points. It is not necessary that the debarkation point be a port. The equipment may be staged at a convenient dock or beach. For open water spills, however, the recovery equipment (barrier, barges) is so large that a port is much more likely to be selected. A review of OSC reports on file with the USCG shows a wide variety of selections (although the precise debarkation point is not always apparent in the report). Some samples:

M/V ORIENTAL WARRIOR (5/25/72): Port of Jacksonville, FL.

HANNAH BARGE 2901 (2/24/75): Breakwater at entrance to Milwaukee Harbor, accessible by road.

T/B TM-10 (7/8/74): Upper Galveston Bay.

ZOE COLOCOTRONI (3/18/73): Bahia Sucia, Cabo Rojo (southwest corner of Puerto Rico).

M/V CORINTHOS (1/31/75): Marcus Hook, PA, B.P. docks.

NO/TK TAMANO (7/22/72): Portland Harbor, Hussey Sound.

BARGE Z-102 (12/9/75): San Juan Harbor and Palo Seco area, Puerto Rico.

USNS JOSEPH MERRELL (12/29/74): Pt. San Luis, CA.

Dredge CARIBBEAN (1/11/75): Miami Harbor, FL.

T/B STC-101 (2/2/76): Reedville and Fleet Pt. MD.
(These were used by contractors as debarkation points.)

SS ARGO MERCHANT (12/15/76): Woods Hole, MA.

Not all cases cited here are open water spills. (The CORINTHOS and CARIBBEAN incidents occurred in harbors.) In none of these cases was the USCG open water boom deployed, and in only

three cases were the ADAPTS deployed (HANNAH 2901, TB Z-102, ARGO MERCHANT). While the majority of incidents were at or near major harbors, three were relatively remote from a major harbor: Cabo Rojo, P.R.; Port San Luis, CA; Reedville, MD. Because of cases such as these, it can not be assumed that the debarkation points for open water spills will always be at a major port. At the other extreme, not every harbor on the U.S. coasts (plus Puerto Rico, Hawaii, and the Virgin Islands) can accommodate the drafts of the USCG vessels likely to be needed at a debarkation point. While the minimum depth required depends on the nature of the spill, this minimum is not likely to be greater than 10 ft. because only the largest cutters (270' WMEC and 378' WHEC) and buoy tenders (180' WLB) have more than 10 ft. drafts. In further support of the 10 ft. reference point, it is noted that the debarkation point for the ARGO MERCHANT incident (Woods Hole, MA) has a channel depth in the 11-15 foot range.

A comprehensive list of ports in the study area was extracted from the World Port Index, Defense Mapping Agency Pub. 150, Fifth Edition (1976). This list contains about 450 ports on the U.S. Great Lakes and East, Gulf and West coasts. If a minimum channel or pier depth of 11 feet is taken as the criterion, the number of potential debarkation points in the study area is about 400.

Another criterion for selecting potential debarkation points is the existence of a lift or crane at the harbor. This would exclude debarkation points unable to load or unload very heavy equipment such as the barrier (17,000 lbs.) or the Type 0 barge (13,000 lbs.). The loading/unloading capability may be necessary unless a buoy tender is available at the debarkation point. If availability of a lift or crane is required in addition to the 11 ft. depth criterion, then the number of potential debarkation points in the study area is 149.

A third criterion for selecting potential debarkation joints is the ability to accept a USCG buoy tender, which has its own crane. The WLB/180 and WLM/175 have 14 and 12 feet drafts, respectively while the WLM/157, WLM/133, WLI/100 and WLI/65 require

7, 9, 5, and 4 feet depths, respectively. Therefore, these last four may use the 400 ports that have 11 feet minimum depth. The WLB/180 and WLM/157, however, would be restricted to ports that have 15 feet minimum depth. There are approximately 342 such ports.

This appendix lists those U.S. and Puerto Rican ports in the World Port Index, 1976 edition, that have lifts or cranes. Pierside and channel depths are also given. Unfortunately, this reference does not give crane capacities, or a breakdown of lift capacities below 24 tons. The codes employed are as follows:

1st Column

- ULO = United States Lake Ontario
- ULE = United States Lake Erie
- ULH = United States Lake Huron
- ULM = United States Lake Michigan
- ULS = United States Lake Superior
- UEC = United States East Coast
- UGC = United States Gulf Coast
- PR = Puerto Rico
- UWC = United States West Coast

2nd Column = Index Number of Reference

3rd Column = Name of Port

4th Column = Country of Port

5th Column = North Latitude, DDMM

6th Column = West Longitude DDDMM

7th Column: Port Size

- L = Large
- M = Medium
- S = Small
- V = Very Small

8th Column: Harbor type

CN = Coastal Natural
CB = Coastal Breakwater
CT = Coastal Tide Gate
RN = River Natural
RB = River Basin
RT = River Tide Gate
LC = Canal or Lake
OR = Open Roadstead
TH = Typhoon Harbor

9th Column: Type of protection afforded

E = Excellent
G = Good
F = Fair
P = Poor
N = None

10th Column: Channel Depth (Feet)

A = 76-over
B = 71-75
C = 66-70
D = 61-65
E = 56-60
F = 51-55
G = 46-50
H = 41-45
J = 36-40
K = 31-35
L = 26-30
M = 21-25
N = 16-20
O = 11-15
P = 6-10
Q = 0-5

11th Column: Anchorage Depth (Feet)

See codes for 8th column.

12th Column: Cargo Pier Depth (Feet)

See codes for 8th column.

13th Column: Cranes

y = one or more cranes
blank = no cranes

14th Column: Lifts

y = one or more lifts
blank = no lifts

In order to aid visualization of the distribution of debarkation facilities of interest to the pollution response problem, two plots were prepared.

Figure E-1: Debarkation ports with more than 10 feet draft in channel and pier areas and a lift or crane.

Figure E-2: Debarkation ports with more than 15 feet draft in channel and pier areas.

Reference: Pub. 150 "World Port Index," Fifth Edition, 1976, Defense Mapping Agency Hydrographic Center, Code NVP3, Washington DC 20390.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ULO	3170	OSWEGO	US	4328	7631	S	RN	E	M	M	M	Y	Y
ULO	3200	ROCHESTER	US	4316	7736	S	RN	E	M	M	M		Y
ULE	3430	BUFFALO	US	4253	7853	L	CB	E	L	M	L	Y	Y
ULE	3450	ERIE	US	4209	8006	S	CN	E	L	M	M	Y	Y
ULE	3460	CONNEAUT	US	4158	8033	S	RN	E	M	L	M	Y	Y
ULE	3470	ASHTABULA	US	4154	8048	S	RB	E	L	L	L	Y	Y
ULE	3490	CLEVELAND	US	4130	8143	L	CB	E	L	L	L	Y	Y
ULE	3500	LORAIN	US	4128	8211	S	RN	E	L	J	L	Y	
ULE	3560	TOLEDO	US	4142	8328	M	RN	E	L	M	L	Y	Y
ULE	3570	MONROE	US	4153	8320	V	RN	E	L	N	N	Y	Y
ULE	3620	DETROIT	US	4220	8302	L	RN	E	M	L	L	Y	Y
ULH	4350	PORT HURON	US	4300	8226	V	RN	E	M	L	M	Y	Y
ULH	4400	BAY CITY	US	4336	8352	S	RN	E	M	M	M	Y	Y
ULH	4410	SAGINAW	US	4326	8356	S	RN	E	N	N	M	Y	Y
ULH	4520	MACKINAW CITY	US	4547	8443	V	LC	P	N	N	N	Y	Y
ULM	4670	LUDINGTON	US	4357	8627	S	LC	E	L	L	N	Y	
ULM	4690	MUSKEGON	US	4314	8616	S	LC	G	L	K	M	Y	Y
ULM	4800	CHICAGO	US	4153	8736	L	CT	G	L	M	M	Y	Y
ULM	4860	MILWAUKEE	US	4302	8753	M	RN	G	L	N	M	Y	Y
ULM	4940	GREEN BAY	US	4431	8801	S	RN	G	M	L	M	Y	Y
ULS	5450	SUPERIOR	US	4644	9204	M	CN	E	M	L	L	Y	Y
ULS	5460	DULUTH	US	4646	9206	M	CN	E	M	L	L	Y	Y
UEC	6600	EASTPORT	US	4454	6659	V	CN	F	H	H	M	Y	Y
UEC	6610	LUBEC	US	4452	6659	V	CN	G	O	O	P	Y	Y
UEC	6630	MACHIAS	US	4443	6728	V	RN	G	P	K	O	Y	Y
UEC	6710	NORTHEAST HARBOR	US	4418	6817	V	CN	F	O	O	P	Y	Y
UEC	6720	SOUTHWEST HARBOR	US	4417	6819	V	CN	G	K	H	O	Y	Y
UEC	6730	MOUNT DESERT	US	4422	6820	V	CN	F	M	M	P	Y	Y
UEC	6810	STONINGTON	US	4409	6840	V	CN	G	N	N	O	Y	Y
UEC	6960	ROCKLAND	US	4406	6906	V	CB	G	N	M	N	Y	Y
UEC	7040	EAST BOOTHBAY	US	4352	6935	V	CN	F	N	H	O	Y	Y
UEC	7050	BOOTHBAY HARBOR	US	4351	6938	S	CN	G	M	H	O	Y	Y
UEC	7070	ROBINHOOD	US	4351	6944	V	RN	G	H	N	O	Y	Y
UEC	7150	PORTLAND	US	4340	7015	M	CN	E	K	L	J	Y	Y
UEC	7210	GLOUCESTER	US	4236	7040	S	CN	G	M	M	M	Y	Y
UEC	7220	BEVERLY	US	4232	7053	V	CN	G	M	M	M	Y	Y
UEC	7230	MARBLEHEAD	US	4230	7051	V	CN	G	M	M	M	Y	Y
UEC	7250	BOSTON	US	4221	7103	L	CN	E	J	H	H	Y	Y
UEC	7280	PLYMOUTH	US	4157	7040	V	CN	F	N	O	O	Y	Y
UEC	7310	HYANNIS	US	4139	7017	V	CN	E	O	O	O		Y
UEC	7320	FALMOUTH	US	4133	7037	V	CN	F	P	P	P	Y	Y
UEC	7350	VINEYARD HAVEN	US	4127	7036	V	CB	G	N	M	M		Y
UEC	7420	PROVIDENCE	US	4148	7124	M	RN	G	L	K	J	Y	Y
UEC	7480	NOANK	US	4119	7159	V	CN	F	P	O	O		Y
UEC	7500	NEW LONDON	US	4121	7205	S	RN	G	K	K	K	Y	Y
UEC	7510	NORWICH	US	4131	7205	V	RN	G	M	M	M		Y
UEC	7520	ESSEX	US	4121	7223	V	RN	G	Q	O	P	Y	Y
UEC	7550	NEW HAVEN	US	4114	7255	S	CB	G	K	N	K	Y	Y
UEC	7570	BRIDGEPORT	US	4110	7311	M	CB	E	L	M	K		Y
UEC	7600	STAMFORD	US	4102	7333	V	RN	G	N	O	O		Y
UEC	7630	BROOKLYN	US	4040	7401	L	RN	E	H	H	H	Y	Y

UEC	7640	MANHATTAN	US	4042	7401	L	RN	E	H	H	H	Y	Y
UEC	7650	YONKERS	US	4056	7354	S	RN	E	P	P	N		Y
UEC	7720	ALBANY	US	4239	7345	M	RN	G	K	J	L	Y	Y
UEC	7750	EDGEWATER	US	4049	7359	V	RN	G	K	K	M	Y	Y
UEC	7760	WEEHAWKEN	US	4046	7401	S	RN	G	H	H	K	Y	Y
UEC	7770	HOBOKEN	US	4045	7401	M	RN	G	H	H	K	Y	Y
UEC	7780	JERSEY CITY	US	4043	7402	M	RN	G	H	H	K	Y	Y
UEC	7790	BAYONNE	US	4041	7406	M	RN	G	K	H	H	Y	Y
UEC	7810	NEWARK	US	4042	7409	M	RB	G	L	J	J	Y	Y
UEC	7820	ELIZABETHPORT	US	4039	7411	S	CN	G	J	J	K	Y	Y
UEC	7830	STAPLETON SI	US	4038	7404		CN	G	H	H	J	Y	Y
UEC	7840	TOMPKINSVILLE SI	US	4038	7404	M	CN	G	H	H	J	Y	Y
UEC	7850	PORT RICHMOND SI	US	4039	7408	S	CN	G	J	J	L	Y	Y
UEC	7860	MARINERS HARBOR SI	US	4038	7410	S	CN	G	J	J	K	Y	Y
UEC	7870	GULFPORT SI	US	4038	7412	S	RN	G	J	J	K	Y	Y
UEC	7890	PORT SOCONY	US	4033	7415	S	RN	G	K	K	L	Y	Y
UEC	7895	BAYWAY	US	4038	7412	V	RN	G	K	K	L	Y	Y
UEC	8010	TUCKERTON	US	3936	7420	V	RN	G	P	P	P		Y
UEC	8050	WILMINGTON	US	3944	7533	M	RN	G	M	M	H	Y	Y
UEC	8080	CHESTER	US	3951	7521	L	RN	G	J	J	K	Y	Y
UEC	8110	PHILADELPHIA	US	3957	7508	L	RN	G	J	J	J	Y	Y
UEC	8130	CAMDEN	US	3957	7508	M	RN	G	J	J	J	Y	Y
UEC	8140	BURLINGTON	US	4005	7452	V	RN	G	O	M	N	Y	Y
UEC	8160	TRENTON	US	4012	7446	V	RN	G	N	N	M	Y	Y
UEC	8200	HAVRE DE GRACE	US	3932	7605	V	RN	G	O	N	O		Y
UEC	8210	BALTIMORE	US	3916	7635	L	RN	G	J	L	J	Y	Y
UEC	8225	ANNAPOLIS	US	3859	7629	V	RN	G	N	K	O	Y	
UEC	8280	NORFOLK	US	3651	7618	L	RN	E	H	M	J	Y	Y
UEC	8290	PORTSMOUTH	US	3649	7618	S	RN	E	H	M	J	Y	Y
UEC	8300	NEWPORT NEWS	US	3658	7626	M	CN	G	H	M	J	Y	Y
UEC	8318	WARWICK	US	3727	7725	S	RN	G	L	L	N	Y	Y
UEC	8320	RICHMOND	US	3732	7725	V	RN	G	N	N	N	Y	Y
UEC	8470	WILMINGTON	US	3414	7757	M	RN	G	K	K	K	Y	Y
UEC	8500	CHARLESTON	US	3247	7955	S	CN	G	K	K	K	Y	Y
UEC	8510	PORT ROYAL	US	3222	8041	V	RN	G	M	N	L	Y	Y
UEC	8530	SAVANNAH	US	3205	8105	M	RN	G	K	H	K	Y	Y
UEC	8550	BRUNSWICK	US	3109	8130	S	RN	G	L	L	L	Y	Y
UEC	8580	JACKSONVILLE	US	3019	8139	M	RN	E	K	M	K	Y	Y
UEC	8610	PALM BEACH	US	2646	8003	V	CN	G	L	P	L	Y	Y
UEC	8630	PORT EVERGLADES	US	2606	8007	M	CN	G	J	J	J	Y	Y
UEC	8640	MIAMI	US	2547	8011	S	CN	G	L	L	K	Y	Y
UGC	8660	KEY WEST	US	2433	8149	S	CN	G	L	N	K	Y	Y
UGC	8670	TAMPA	US	2755	8227	M	CN	G	K	M	K	Y	Y
UGC	8730	APALACHICOLA	US	2943	8459	V	RN	G	P	P	Q	Y	Y
UGC	8770	MOBILE	US	3041	8807	L	RN	G	J	K	J	Y	Y
UGC	8800	GULFPORT	US	3021	8905	S	CB	G	K	L	K	Y	Y
UGC	8810	SLIDELL	US	3016	8947	V	LC	G	P	P	P		Y
UGC	8830	PORT SULPHUR	US	2929	8941	V	RN	G	J	H	H	Y	
UGC	8860	NEW ORLEANS	US	2957	9003	L	RN	E	J	A	J	Y	Y
UGC	8970	BATON ROUGE	US	3027	9106	S	RN	G	K	H	K	Y	Y
UGC	8990	GRAND ISLE	US	2914	9000	V	CN	G	P	P	Q	Y	Y
UGC	9000	MORGAN CITY	US	2942	9113	V	RN	G	P	H	P	Y	Y

POTENTIAL DEBARKATION POINT

UGC	9040	LAKE CHARLES	US	3013	9315	S	RN	G	J	L	J	Y	Y
UGC	9080	PORT ARTHUR	US	2950	9358	M	LC	G	J	J	J	Y	Y
UGC	9140	BEAUMONT	US	3005	9405	M	RN	G	J	L	J	Y	Y
UGC	9150	GALVESTON	US	2919	9447	L	CN	G	J	L	K	Y	Y
UGC	9160	TEXAS CITY	US	2923	9455	S	CN	G	K	L	K	Y	Y
UGC	9240	HOUSTON	US	2945	9517	L	RN	G	J	K	K	Y	Y
UGC	9250	FREEPORT	US	2857	9520	V	RN	G	K	L	J	Y	Y
UGC	9300	CORPUS CHRISTI	US	2749	9724	M	CN	G	J	K	K	Y	Y
UGC	9340	BROWNSVILLE	US	2557	9724	S	LC	G	K	K	K	Y	Y
PR	11110	SAN JUAN	RQ	1828	6607	M	CN	E	K	L	K	Y	Y
PR	11170	ENSENADA HONDA	RQ	1814	6538	S	CN	E	J	K	K	Y	Y
PR	11260	PONCE	RQ	1759	6637	S	CN	F	L	N	L	Y	Y
PR	11280	GUANICA	RQ	1758	6655	S	CN	E	K	M	K	Y	Y
UWC	16010	SAN DIEGO	US	3243	11711	M	CN	E	J	J	K	Y	Y
UWC	16070	LONG BEACH	US	3346	11811	M	CB	E	F	K	E	Y	Y
UWC	16080	LOS ANGELES	US	3345	11815	L	CB	E	G	K	E	Y	Y
UWC	16120	PORT HUENEME	US	3409	11912	V	CB	E	K	L	L	Y	Y
UWC	16270	SANTA CRUZ	US	3658	12201	V	CN	F	P	L	L	Y	Y
UWC	16300	SAN FRANCISCO	US	3749	12225	L	CN	E	G	L	J	Y	Y
UWC	16330	ALAMEDA	US	3747	12216	S	CN	E			L	Y	Y
UWC	16340	OAKLAND	US	3749	12220	L	CN	E	L		L	Y	Y
UWC	16410	MARE ISLAND	US	3806	12216	S	CN	E	L	L	L	Y	Y
UWC	16440	CROCKETT	US	3803	12213	V	CN	E	K	M		Y	
UWC	16520	STOCKTON	US	3757	12118	S	RN	E	L		L	Y	Y
UWC	16540	RIO VISTA	US	3809	12142	V	RN	E	L		M		Y
UWC	16590	SACRAMENTO	US	3835	12130	S	RN	E	L		L	Y	
UWC	16850	ASTORIA	US	4612	12350	S	RN	E	H		K	Y	Y
UWC	16900	LONGVIEW	US	4608	12256	S	RN	E	L		K	Y	Y
UWC	16940	PORTLAND	US	4531	12240	L	RN	E	L	L	K	Y	Y
UWC	16950	VANCOUVER	US	4538	12241	M	RN	E	L		K	Y	Y
UWC	17030	WILLAPA HARBOR	US	4641	12345	V	RN	E	L		M	Y	Y
UWC	17040	WESTHAVEN COVE	US	4655	12407	V	RN	E	M		N	Y	Y
UWC	17060	ABERDEEN	US	4659	12349	S	RN	E	L		K	Y	Y
UWC	17080	HOQUIAM	US	4658	12354	S	RN	E	L		K	Y	Y
UWC	17120	PORT ANGELES	US	4807	12326	S	CN	G	D	H	G	Y	Y
UWC	17160	PORT TOWNSEND	US	4807	12245	S	CN	G	P	G	N	Y	Y
UWC	17430	BREMERTON	US	4734	12239	M	CN	E	H	H	H	Y	Y
UWC	17440	PORT ORCHARD	US	4732	12238	V	CN	E	K	K	K	Y	
UWC	17700	TACOMA	US	4717	12225	M	CN	E	A	A	G	Y	Y
UWC	17730	SEATTLE	US	4736	12220	L	CN	E	K	A	A	Y	Y
UWC	17780	MUKILTEO	US	4757	12218	V	CN	E	J	J	J	Y	Y
UWC	17790	EVERETT	US	4800	12213	S	CN	E	L	K	J	Y	Y
UWC	17920	FRIDAY HARBOR	US	4832	12301	V	CN	E		J	N	Y	Y
UWC	17940	ROCHE HARBOR	US	4837	12310	V	CN	E		L		Y	Y
UWC	18040	ANACORTES	US	4831	12237	S	CN	E		F	J	Y	Y
UWC	18050	BELLINGHAM	US	4845	12230	S	CN	E		K	K	Y	Y

POTENTIAL DEBARKATION PORTS

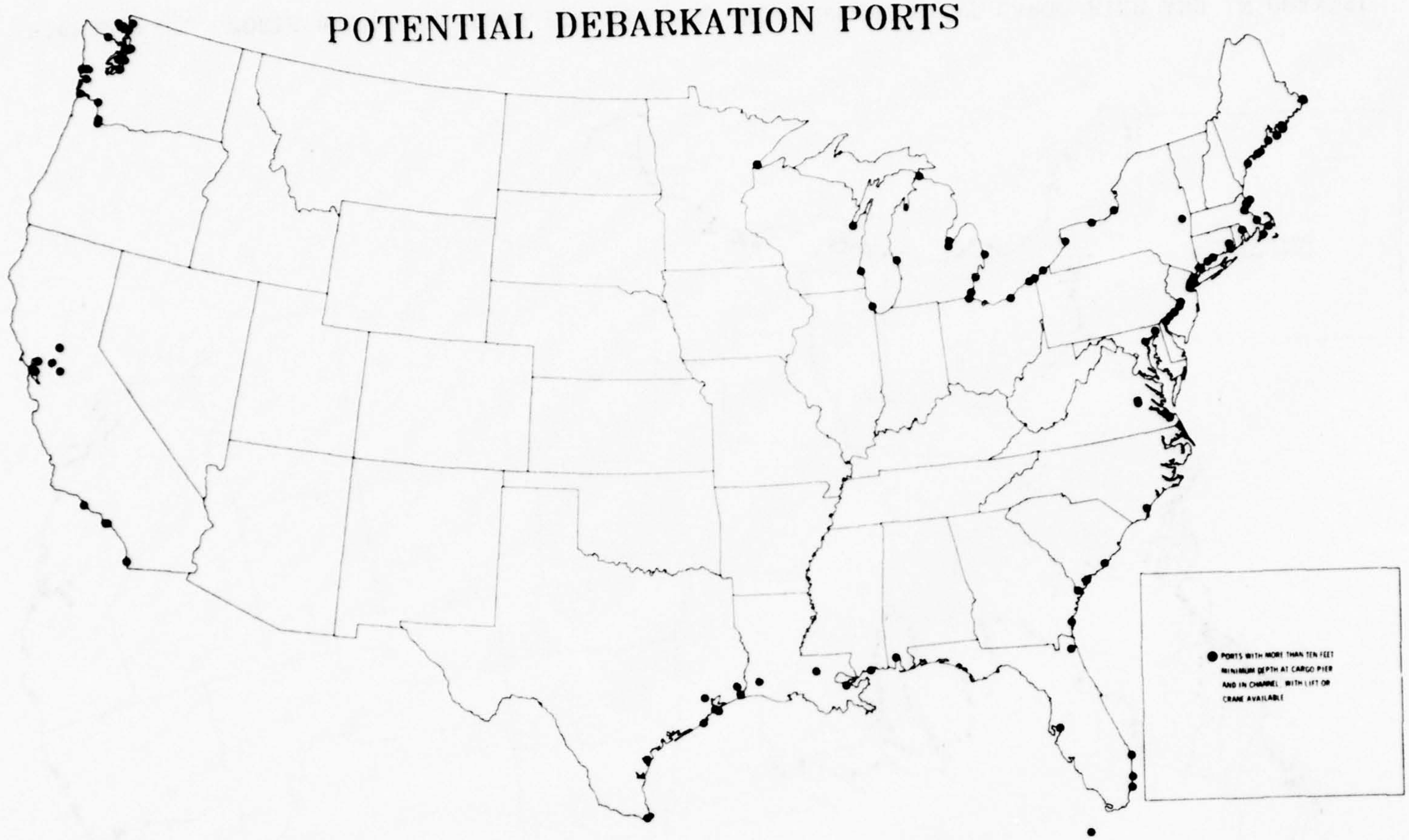

FIGURE E-1. PORTS WITH MORE THAN TEN FEET MINIMUM DEPTH AT CARGO PIER AND IN CHANNEL, AND HAVING A LIFT OR CRANE AVAILABLE

POTENTIAL DEBARKATION PORTS

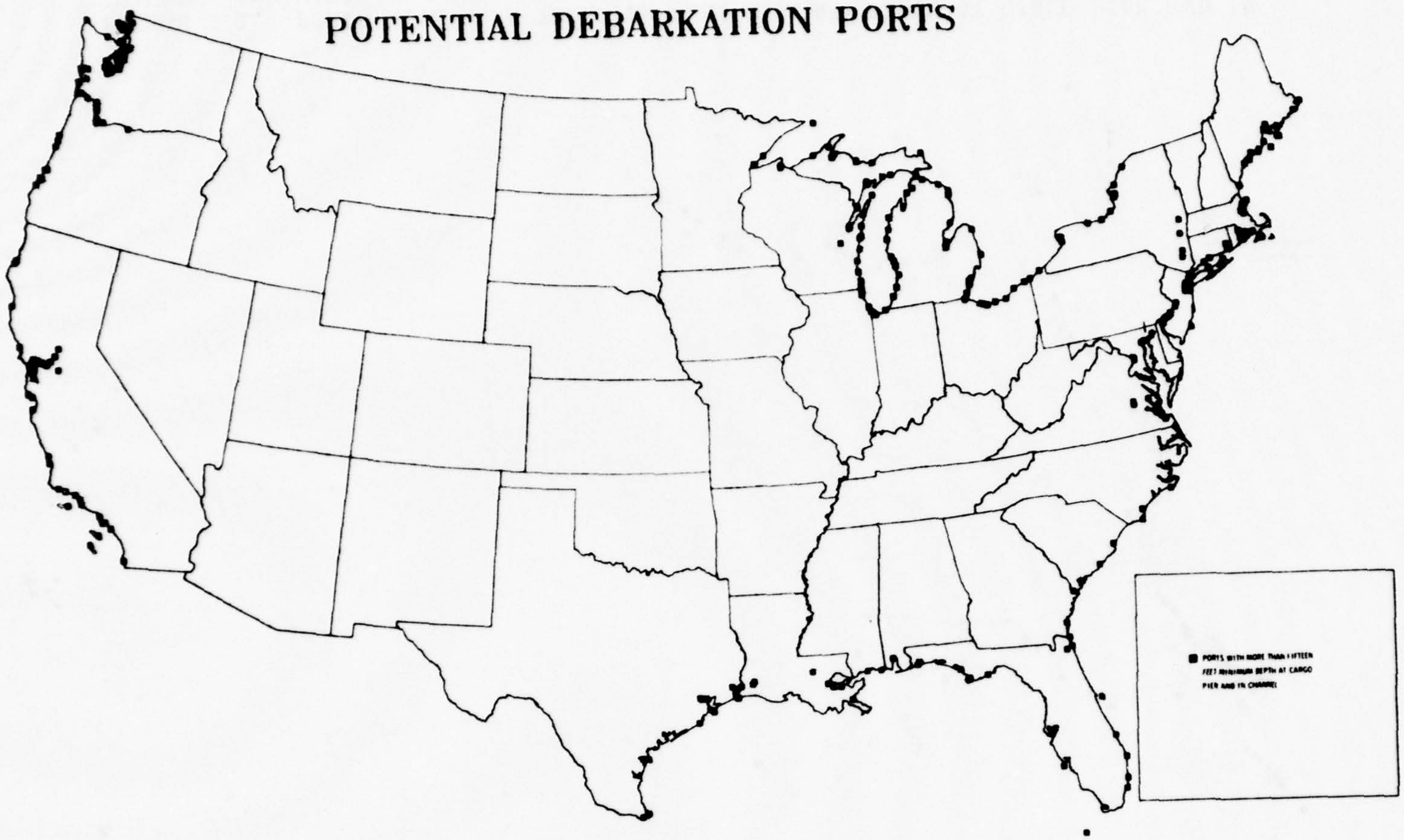

FIGURE E-2. PORTS WITH MORE THAN FIFTEEN FEET MINIMUM DEPTH AT CARGO PIER AND IN CHANNEL

APPENDIX F:
LOAD/RANGE TRADEOFF CURVES FOR THE HH3-F AND HC130 AIRCRAFT

This Appendix presents approximate curves for trading off payload and range for the HH3-F helicopter and the Lockheed Hercules Models HC130B and HC130H. The approximations are based on discussions with USCG search and rescue personnel (G-OSR-2) and the operating manuals of the aircraft involved. The curves and equations are not accurate enough for planning a specific mission, but will suffice for system analysis.

HH3-F HELICOPTER

Three limitations on range and payload are taken into account for the HH3-F. They are:

a. The gross weight of the HH3-F cannot exceed 22,050 lbs. at any time during the flight. The gross weight is a maximum at takeoff in the missions to be considered.

b. The gross weight cannot exceed a value, MGWHOGE, when the aircraft is hovering out of the ground effect. The value assumed here is 20,200 lb., corresponding to 22°C air temperature and sea level pressure.

c. The fuel carried cannot exceed the normal tank capacity of the HH3--about 4200 lb. for JP-4.

Additional fuel cannot be carried without modification and reduction in interior space for the payload.

These three limitations may be expressed as inequalities involving the payload, L, the mission range, R, and other mission and aircraft parameters:

$$L \leq MGW - W_{AC} - F_R - f_o \frac{R}{V_o} - f_H t_H - f_R \frac{R}{V_R} \qquad (1)$$

$$L \leqslant MGWHOGE - W_{AC} - F_R - f_h t_h - f_r \frac{R}{V_R} \tag{2}$$

$$F_R + f_o \frac{R}{V_o} + f_H t_H + f_R \frac{R}{V_R} \leqslant C_T \tag{3}$$

where

MGW	=	maximum gross weight, lbs.
MGWHOGE	=	maximum gross weight when hovering out of ground effect, lbs.
W_{AC}	=	weight of empty aircraft plus crew, lbs.
F_R	=	weight of fuel reserve, lbs.
f_o, f_H, f_R	=	fuel consumption in outbound travel, hovering, and return travel, lbs/hr
V_o, V_R	=	speed outbound and returning, knots
t_H	=	hovering time, hrs.
C_T	=	fuel tank capacity, lbs.

The values for the above parameters will, in general, depend on the mission. Three missions are considered; the values of the parameters assumed for each are tabulated in Table F-1, and the resultant L-R limits are plotted in Figure F-1.

Mission 1: One-Way, Internal Payload

This mission is to transport cargo from base to base; i.e., takeoff, straight line flight, landing. The hovering restriction, b., does not apply. It is assumed that the payload is carried internally; i.e., equipment and/or personnel are loaded into the cargo area and not removed until landing. A crew of four is assumed, at 200 lbs. per crew member. The fuel reserve is adequate for 20 minutes, based on USCG practice.

As seen in Figure F-1, the zero-range payload is 6350 lbs., and the max-range payload is 2600 lb. The maximum range is 410 n.mi.

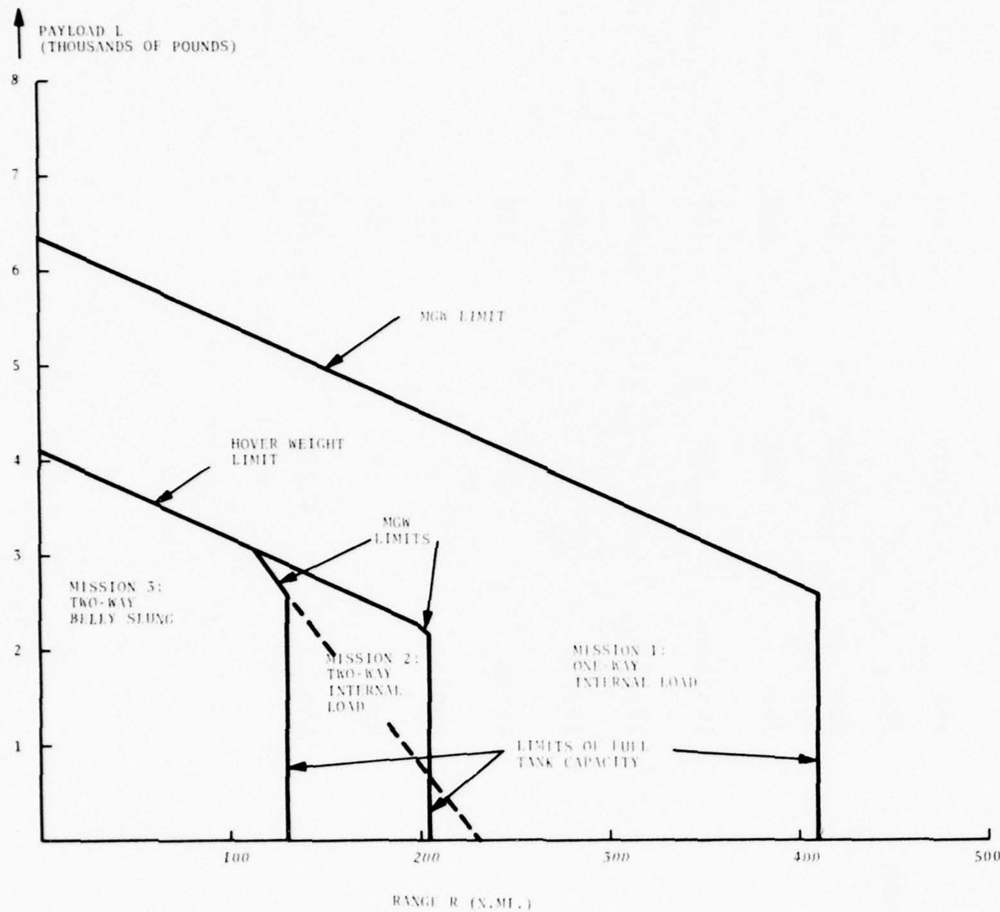

FIGURE F-1 PAYLOAD-RANGE RELATIONS FOR HH3F HELICOPTER

TABLE F-1 PARAMETERS FOR THREE HH3-F MISSIONS

Parameter	Units	Mission 1	Mission 2	Mission 3
MGW	lbs	22,050	22,050	22,050
MGWHOGE	lbs	-	20,200	20,200
W_{AC}	lbs	15,300	15,300	15,300
F_R	lbs	400	400	400
f_O	lbs/hr	1,200	1,200	1,000
f_H	lbs/hr	-	1,200	1,200
f_R	lbs/hr	-	1,200	1,200
V_O	knots	130	130	60
V_R	knots	-	130	130
t_H	hrs	-	20	20
C_T	lbs	4,200	4,200	4,200

Mission 2: Two-Way, Internal Payload

In this mission, the helicopter proceeds from its base to the spill site, where it hovers for 20 minutes while the payload is lowered out of the cargo door, and then returns to its takeoff base.

As seen in Figure F-1, the hovering weight limit restricts the payload for almost all ranges up to the fuel tank capacity range. MGW is a limiting factor only for the ranges 200 n.mi. to 205 n.mi. It will be noted that at the maximum range of 205 n.mi., the maximum payload is just 1/2 of that for the one-way mission of equal range. This fraction is higher at shorter ranges, rising to 65% at zero range.

Mission 3: Two-Way, Belly Sling Payload

If the load is slung under the belly the speed on the outbound leg is reduced to 60 knots and fuel consumption to 1000 lbs/hr, according to USCG experience. The hovering weight limit and return leg are the same as in Mission 2, where the payload is *internal*. Because of the increased fuel consumption on the outbound leg (16.7 lbs/n.mi. compared to 9.2 lbs/n.mi.) the fuel tank capacity limits mission 3 to 130 n.mi., or 75 n.mi. less than if the cargo were carried internally. As in the case of the internal cargo mission, the belly sling method is limited in range primarily by the cruising speed rather than the MGW limit.

HC 130 FIXED WING

The USCG maintains two versions of the HC130 aircraft. The H-version has greater range and a higher maximum gross weight. Operational parameters for the two versions are shown in Table F-2. These parameters are based on common USCG practice.

In determining the maximum payload-range combinations for the C130, account must be taken of the fuel and gross weight limitations, of the fuel reserve requirements, and of the weight of the auxiliary tanks themselves.

TABLE F-2 PARAMETERS FOR TWO HC130 AIRCRAFT

	HC130-B	HC130-H
Cruise speed, kts	290	300
Fuel consumption, lbs/hr[1]	4,500	5,000
Minimum operating wt, lbs	70,000	70,000
Nominal operating wt, lbs[2]	85,000	90,000
Wing fuel capacity, lbs	45,000[3]	45,000
External tank capacity, lbs	-	18,000
Reserve fuel required, lbs	- 45% min or 10% of total -	
Weight of external tanks, lbs	-	2,000

[1] Based on JP4 weight fuel, 6.5 lbs/US gal.

[2] Approximate weight of equipped aircraft, exclusive of fuel and payload and external tanks.

[3] Including auxiliary tanks.

HC130-B

Figure F-2 shows the maximum gross aircraft weight, less fuel, as a function of the total fuel weight. (The gross aircraft weight, less fuel, is the nominal operating weight plus payload.) It may not exceed the values shown in Figure F-2 at any point in the flight in order to stay within the recommended 2.5G maneuver factor. Since the gross weight, less fuel, is constant during a flight, while the fuel weight decreases with time, (not necessarily to zero) the operating point moves on the chart from right to left on a horizontal line segment of length equal to the fuel expended, at a distance above the x-axis equal to the gross weight less fuel.

Using the chart of Figure F-2, it is possible to determine the maximum achieveable gross weight, less fuel, as a function of the mission range. The latter is defined as the one-way distance from takeoff to landing. The result is shown in Figure F-3. The reserve and nominal fuel consumption and speed shown in Table F-2 were employed in constructing Figure F-3.

Finally, the payload is determined by subtracting aircraft operating weight (nominally 90,000 lbs. for the HC130-B) from the Vertical axis of Figure F-3 for the selected range.

HC130-H

The payload-range relation for the H-version is obtained in the same way as for the B-version. The combinations of gross weight, less fuel, and total fuel that lie under the lines of Figure F-4 are permissible at load factors up to 2.25G in the H-version. The corresponding ranges, allowing for the fuel reserves, speed, and fuel consumption rates shown in Table F-2 are plotted in Figure F-5. As is the case of the B-version, the nominal operating weight of about 90,000 lbs. must be subtracted from the gross weight less fuel. Finally, 2000 lbs. must be subtracted from the payload if the aircraft is fitted with external tanks.

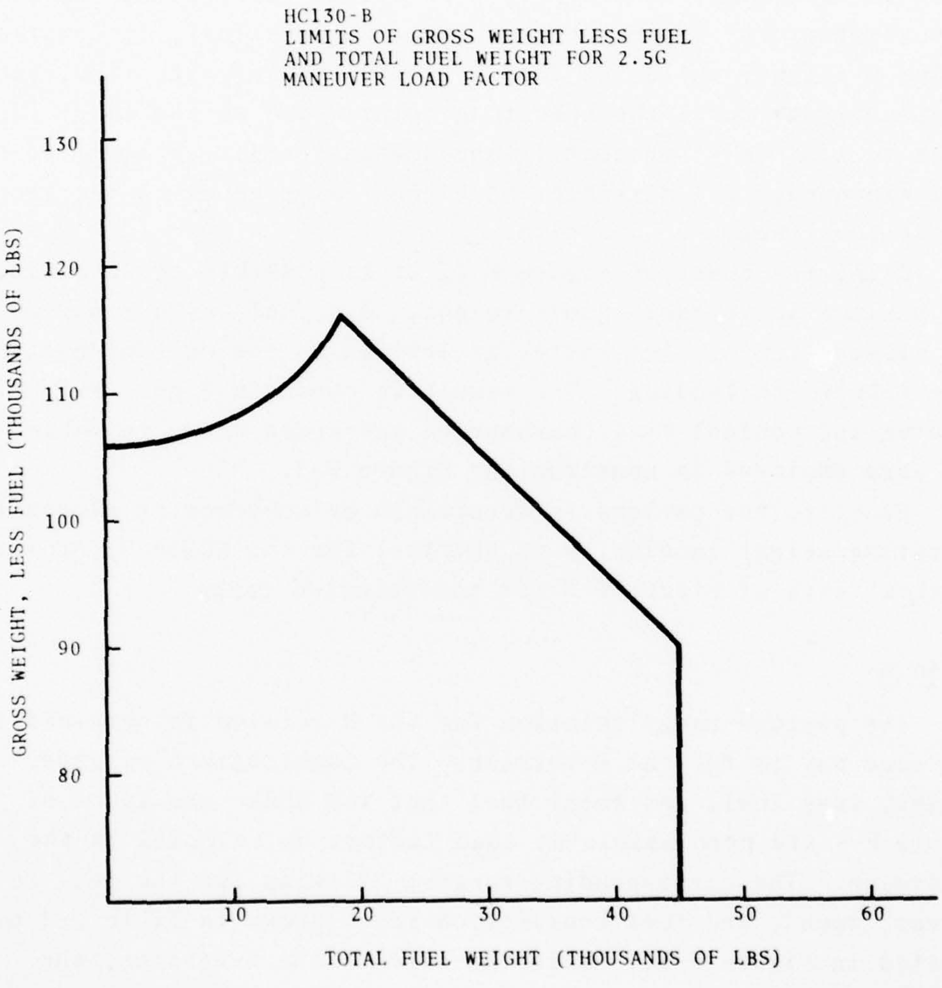

FIGURE F-2 GROSS WEIGHT-FUEL RESTRICTIONS FOR HC130-B AIRCRAFT

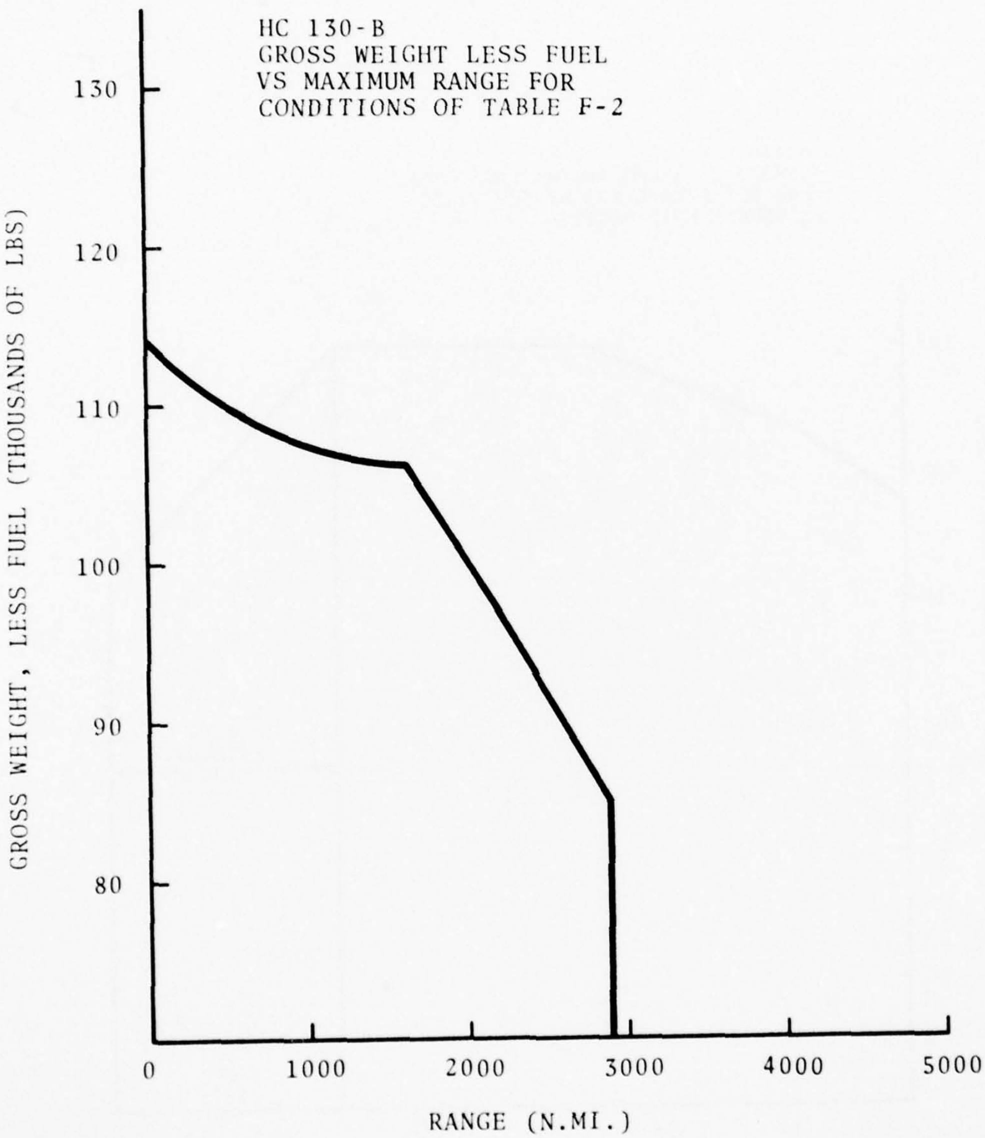

FIGURE F-3 GROSS WEIGHT-RANGE RELATIONS FOR HC130-B AIRCRAFT

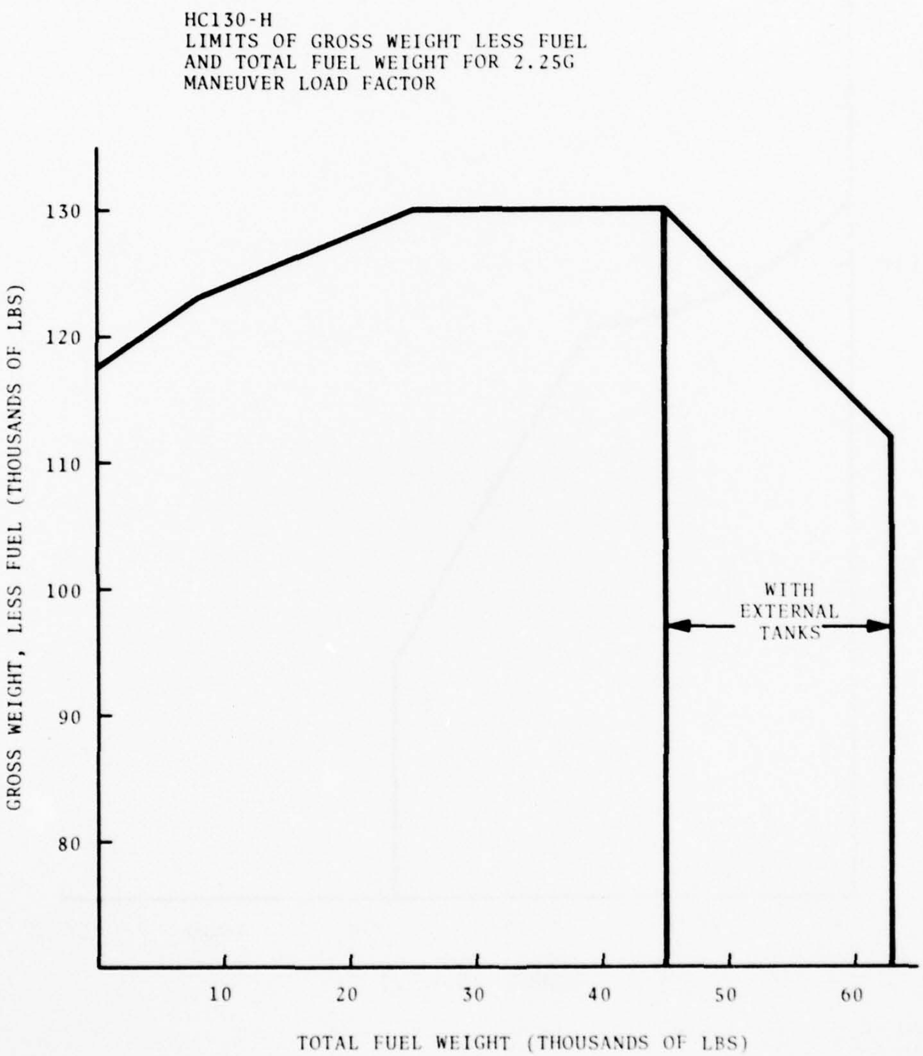

FIGURE F-4 GROSS WEIGHT-FUEL RESTRICTIONS FOR HC130-H AIRCRAFT

HC 130-H
GROSS WEIGHT LESS FUEL
VS MAXIMUM RANGE FOR
CONDITIONS OF TABLE F-2

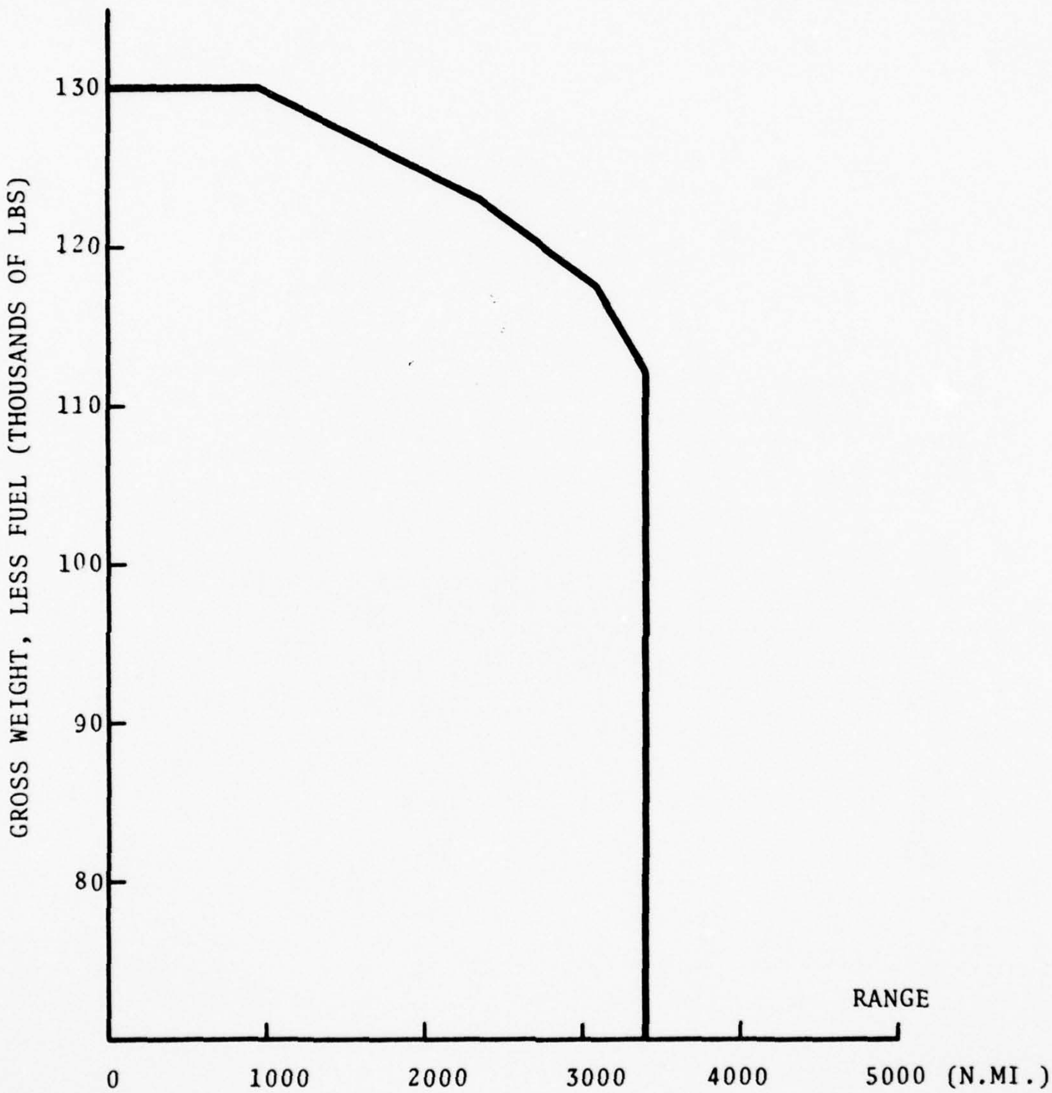

FIGURE F-5 GROSS WEIGHT-RANGE RELATION FOR HC130-H AIRCRAFT

APPENDIX G:
CURRENT U.S. MILITARY HEAVY HELICOPTER CHARACTERISTICS

BOEING VERTOL MODELS 114 AND 234 (CHINOOK SERIES)

The Chinook CH-47 is a U.S. Army, all-weather, medium transport helicopter. The latest U.S. version is the CH-47C, for which the following data apply under 4 conditions of operation, A, B, C, and F (ferry)

	A	B	C	F
Weight empty, lbs	21,464	21,464	21,633	21,162
Payload, lbs, internal)	11,650	6,400	21,700	00
T-O weight, lbs	38,500	33,000	45,400	46,000
Cruise speed, kts	139	137	114	133
Mission radius	100 (1)	100 (1)	20 (1)	1,156 (2)

Appx. fuel consumption, lbs/hr 2500

Cabin length, ft/in......................30/2
width (mean, ft/in.................. 7/6
width, at floor, ft/in.............. 8/3
height, ft/in....................... 6/6
floor area, sq. ft.................. 226
Usable volume, cu. ft...............1474

A: T-O gross weight = design gross weight

B: T-O gross weight = gross weight to hover out of ground effect at 6,000 ft and 95°F

C: T-O gross weight = gross weight to **hover** out of ground effect at sea level, International Standard Atmosphere

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(1) Maximum distance from base before return, with 10% reserve
(2) One-way distance, 10% reserve.

Source: Jane's All the World's Aircraft, 1976-1977

UTTAS - UTILITY TACTICAL TRANSPORT AIRCRAFT SYSTEM

The U.S. Army will replace the UH-1H Iroquois assault transport by this twin turbine combat assault squad transport in the late 1970's. The following data are for the Boeing YUH-61A version:

	YUH-61A
Weight empty, lbs	9,750
Max payload, lbs	5,924
Max useable fuel, lbs	2,288
Cruising speed, kts	145
Range at cruise speed, n. mi.(1)	321
Mission T-O weight, lbs	15,157
Max T-O weight, lbs	19,700
Cabin length, ft.in.	12'8"
max width, ft.in.	7'2"
max height, ft.in.	4'6"
Volume, cubic ft.	412

(1) 30 minute reserves

SIKORSKY-64 SKYCRANE

This heavy lift twin turbine helicopter was intended as a troop transport, minesweeper, cargo and missile transporter, anti-submarine aircraft, and field hospital. It has designations CH-54A, (U.S. Army, 1963), CH-54B (U.S. Army, 1968), plus commercial versions.

Weight empty, lbs	19,234
Max T-O weight, lbs	42,000
Max payload, lbs	20,000
Max fuel, lbs (@ 6.5 lb/gal)	8,580
Typical Mission (One-Way)	
T-O weight, lbs	38,000
Cruise speed, kts	91
Fuel, lbs	8,580
payload, lbs	10,000
Range, with 10% reserve, n.mi.	200
Payload Dimensions (Internal dimensions of external pod)	
Length	27'5"
Width	8'10"
Height	6'6"

CH-53A SEA STALLION (U.S. NAVY) 2-TURBINE

The first of these heavy assault transport helicopters was delivered in 1966. Versions are: CH-53A, RH-53A, HH-53B, HH-53C, HH-53 Pave Low III (USAF), CH-53D, RH-53D, plus non-military versions. Data for the CH-53D:

Weight empty, lbs	23,485
Mission T-O weight, lbs	36,400
Max T-O weight, lbs	42,000
Cruising speed, kts	150
Fuel, lbs, with 10% reserve	4,076
Range at 4,076 lb fuel, 150 kts	223 n. mi.
Payload @ 223 n. mi. range, lbs	8,839
Cabin, length	30'0"
max width	7'6"
max height	6'6"

CH-53E (U.S. NAVY) 3-TURBINE

This is a three-engine version of the S-65A. The U.S. Navy plans to use the CH-53E for vertical on-board delivery operations, to support mobile construction battalions, and to remove damaged aircraft from decks.

Weight empty, lbs	32,048
Typical mission	
T-O weight, lbs	56,000
Cruising speed, kts	150
Range, n.mi.	266
Internal payload at 100 n.mi. range, lbs.	30,000
Cabin	
Length	30'0"
Width at Maximum	7'6"
Height at Maximum	6'6"

NOTE: The following aircraft evolved from the U.S. Navy SH-3A Sea King, first ordered in 1957 and flown in 1959; their performance characteristics are not dissimilar enough from the USCG HH3F to warrant separate tabulation. Sikorsky designations S-61A, S-61B, S-61F, S-61R; Military Designations RH-3A, SH-3A, CH-124, HH-3A, VH-3A, SH-3G, SH-3H, S-61R, CH-3C, CH-3E.

APPENDIX H:
AVAILABILITY OF USCG TOWING VESSELS

It is necessary to develop the statistics of the time required to make available at a USCG coastal equipment storage site one of the USCG cutters or boats that is suitable for towing the FSD or similar hull, loaded with pollution control equipment, to a debarkation point, or directly to a spill.

SELECTION OF VESSELS

In selecting USCG vessels suitable for towing duty on short notice, vessels less than 40 feet long were excluded. Although it is possible that some vessels less than 40 feet long can perform this duty, the only test information available (Reference 7.1, PE-24) is for the UTB/41. This reference merely states that the 41 foot UTB successfully towed the loaded FSD at 12 knots on several occasions.

Not all USCG vessels of 40 foot length or greater were included in the calculations. Icebreakers (WAGB), Reserve Training Cutters (WTR), Construction Tenders (WLIC), River Buoy Tenders (WLR), Lightships (604, 612, 613), Training Cutters (WIX) and Oceanographic Cutters (WAGO) were judged not suitable or not generally available for pollution response duty. Of those that are included some are not usually underway along the full length of District coasts, and have been treated with a nominal coastline distance D, as explained below.

The use of the 378 WHEC for pollution response is slightly compromised by its draft (21 feet) which makes it unsuitable for some ports. Nevertheless, the FSD and similar towed vessels are more likely to be stationed with pollution control equipment at the larger ports where draft is not a serious limitation on use of the 378 WHEC. Hence, the 378 has been included in the list.

DATA AND MODELS

The availability models to be described were tailored to existing data. The data are derived from the Annual Abstract of Operations for 1975, Reference H-1. These volumes are compiled from forms CG-3273A (aircraft), CG-3273B (boats), CG-3273C (cutters), as per Commandant Instruction 3123.7E. The data were provided by USCG G-OP; the 1975 report was the latest available in documented form. It provides adequately accurate statistics for our purposes, because cutter and boat deployments have not changed substantially since 1975.

The Abstract of Operations gives, for each cutter type, the annual hours underway, the hours in Bravo-6 standby, the hours in other standby, and the hours in maintenance. For boats, there is given the annual hours underway, the hours in standby, the hours in maintenance, and the hours in storage. The following approximations are made:

(a) Cutters and boats in maintenance or storage are unavailable.

(b) Cutters in Bravo-6 or less status are available, on the average, in 3 hours.

(c) Cutters in standby other than Bravo-6 are available, on the average, in 6 hours.

(d) Boats in standby status are available, on the average, in 3 hours.

(e) Boats or cutters underway are uniformly distributed along the coastline of their District, and, upon receipt of request for towing assistance, immediately proceed at full speed to the equipment (sled) location.

(f) The possible sled/equipment locations are uniformly distributed along the coastline of the district.

From assumptions (e) and (f) one can determine the probability distribution of the availability time for a vessel under way in terms of D, the length of the District coastline, and V, the maximum speed of return of the vessel to the site. The distribution

is shown in Figure H-1(c), where it is seen that the probability the vessel will return in t hours is just $P = 2Vt/D - (Vt/D)^2$. If there are N similar vessels distributed along the coast, then the probability that one or more will be available in t hours is $1 - (1 - P)^N$ or $1 - (1 - Vt/D)^{2N}$.

Further assumptions are now made regarding the availability of cutters on Bravo-6 status, on Bravo-X status (where $x \geq 6$) and boats on standby status. The distribution of availability time for three cases is assumed to be shown in Figure H-3. These diagrams essentially, quantify the uncertainties expressed in assumptions (b), (c) and (d).

From the preceding it can be seen that the probability that one or more cutters will be available in t hours or less is $P_c(t)$:

$$P_c(t) = 1 - (1 - P_{uc})^{N_{uc}} (1 - P_6)^{N_6} (1 - P_X)^{N_x} \qquad (1)$$

where P_{uc}, P_6, and P_x are the probability functions of t shown in Figures H-1(c), H-2(a) and H-2(b) for cutters underway, on Bravo-6 status, and on standby other than Bravo-6. Similarly, the probability that one or more boats will be available in t hours or less is

$$P_B(t) = 1 - (1 - P_{uB})^{N_{uB}} (1 - P_S)^{N_S} \qquad (2)$$

where P_{uB} and P_S are the probability functions of t shown in Figures H-1(c) and H-3(c) for boats underway and in standby status.

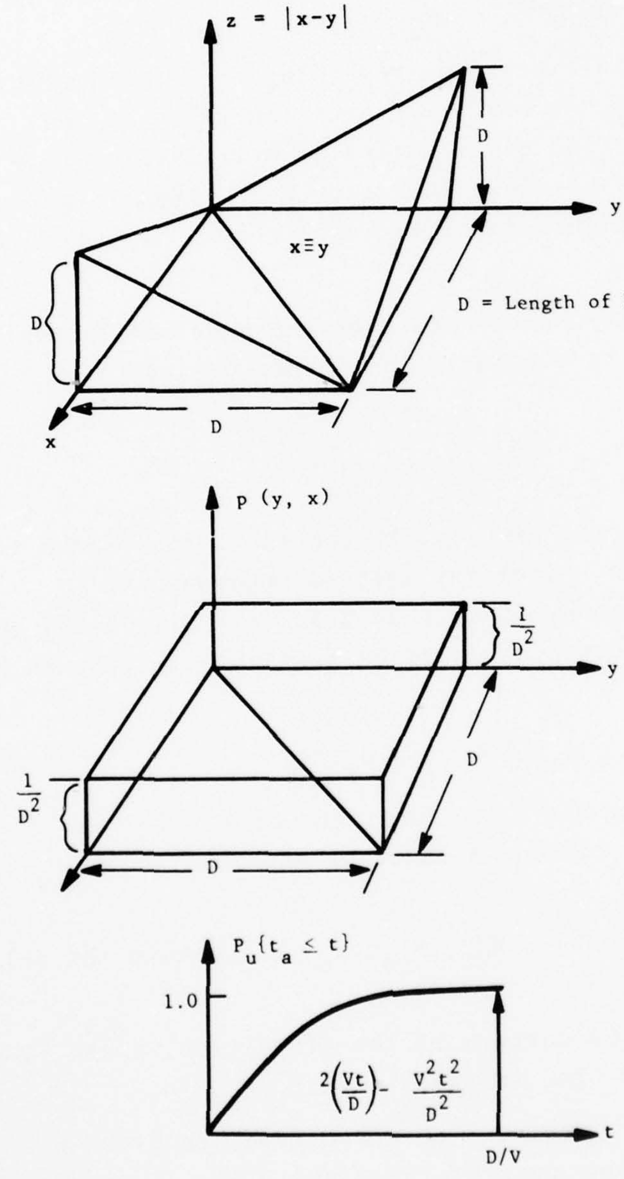
In (1) and (2), the numbers N_{uC}, N_{uB}, N_6, etc., have the following meanings:

N_{uC} = Average number of cutters of the given type, speed V, underway at any time in the District

N_6 = Average number of cutters of given type, on Bravo-6 status, at any one port of the district

N_X = Same as N_6, but for Bravo-X status

x = distance of equipment site along coast; y = distance of vessel underway along coast



(a) Distance z from site to vessel as a function of site and vessel location

(b) Probability density distribution assumed for site and vessel locations, x and y.

(c) Cumulative distribution for availability times, t_a ($\equiv zV$), derived from (a) and (b), for vessels underway.

FIGURE H-1. DISTRIBUTION OF AVAILABILITY TIMES FOR VESSELS UNDERWAY

AD-A070 816 TRANSPORTATION SYSTEMS CENTER CAMBRIDGE MA F/G 13/2
DEPLOYMENT REQUIREMENTS FOR U.S. COAST GUARD POLLUTION RESPONSE--ETC(U)
FEB 79 J BELLANTONI, J GARLITZ, R KODIS
UNCLASSIFIED TSU-USCG-79-2-2 USCG-D-14-79-2 NL

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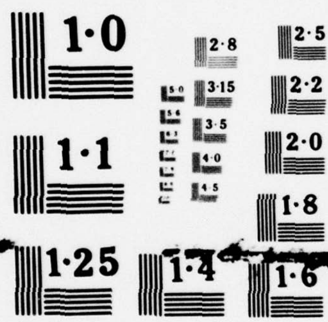

NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

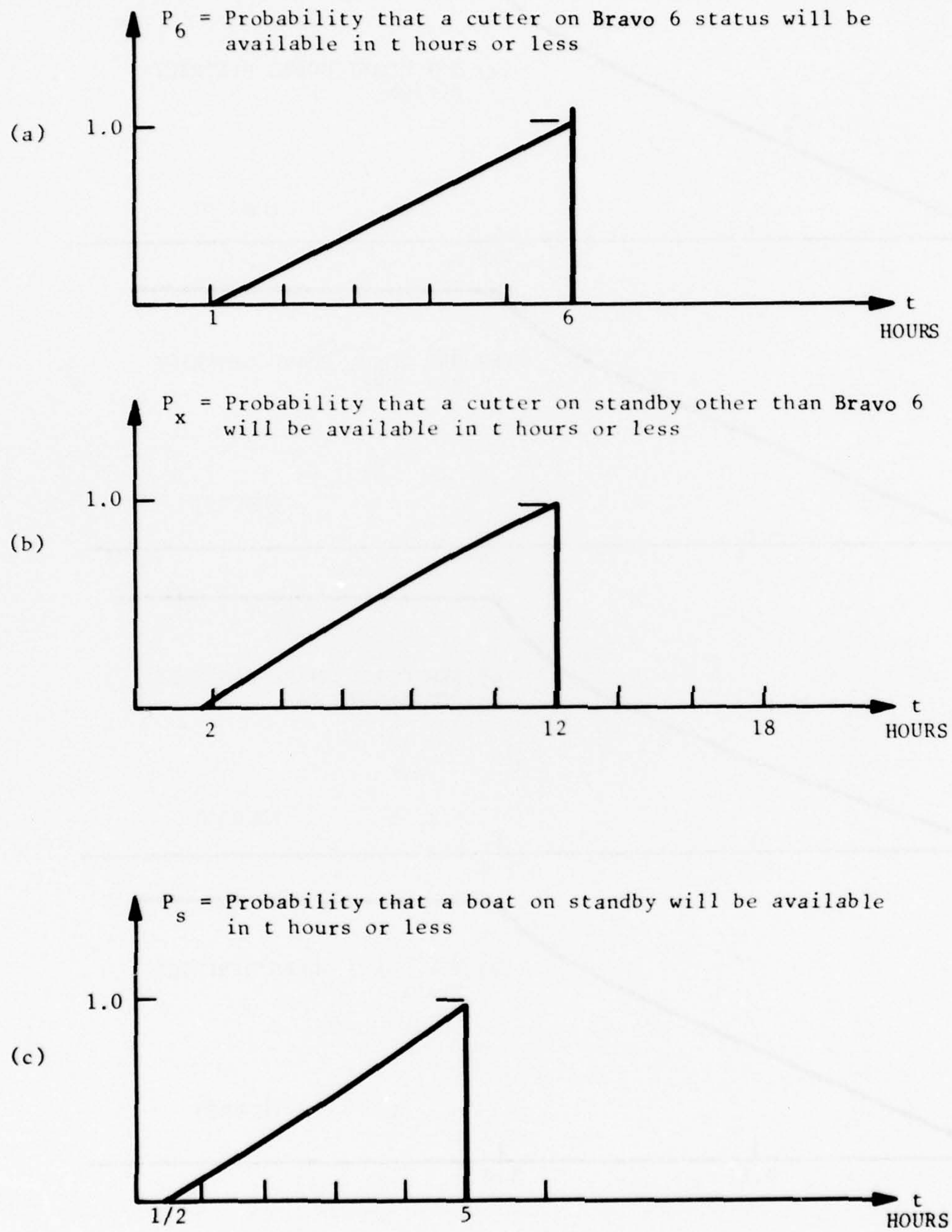

FIGURE H-2. ASSUMED DISTRIBUTION OF AVAILABILITY TIMES FOR BOATS AND CUTTERS ON READY STATUS

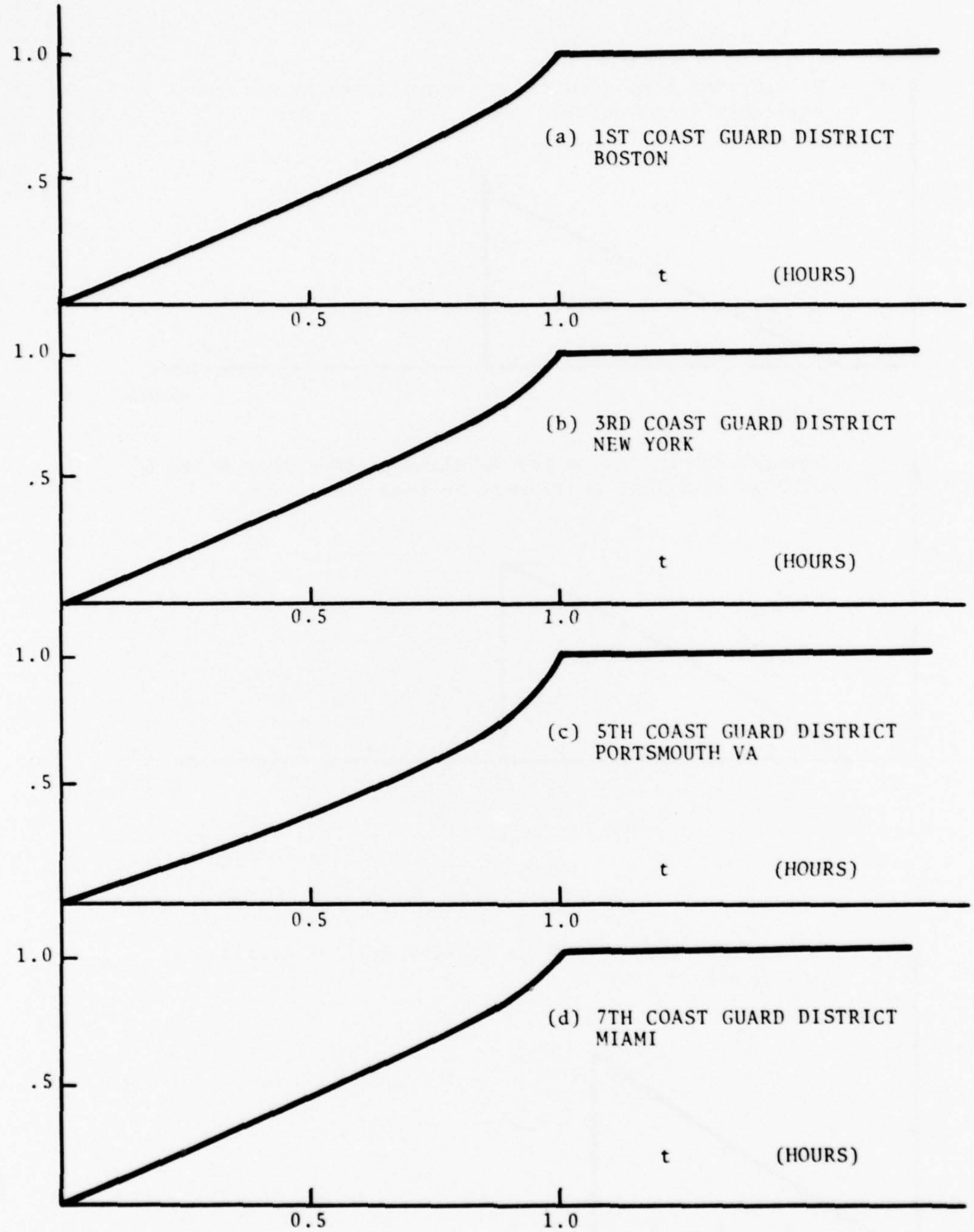

FIGURE H-3. **PROBABILITY OF CUTTER AVAILABILITY IN t HOURS OR LESS (a-d).**

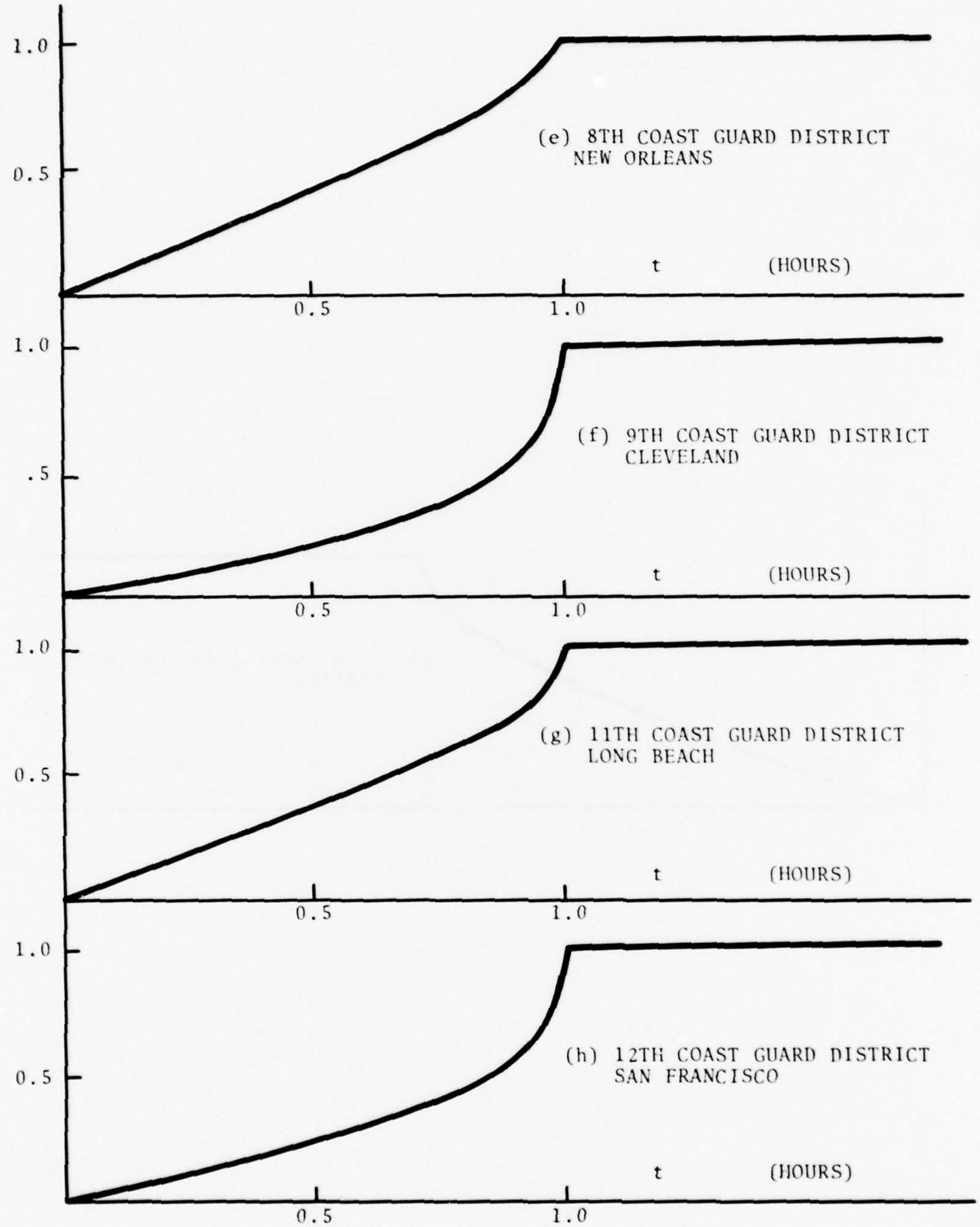

FIGURE H-3. **PROBABILITY OF CUTTER AVAILABILITY IN t HOURS OR LESS (e-h).**

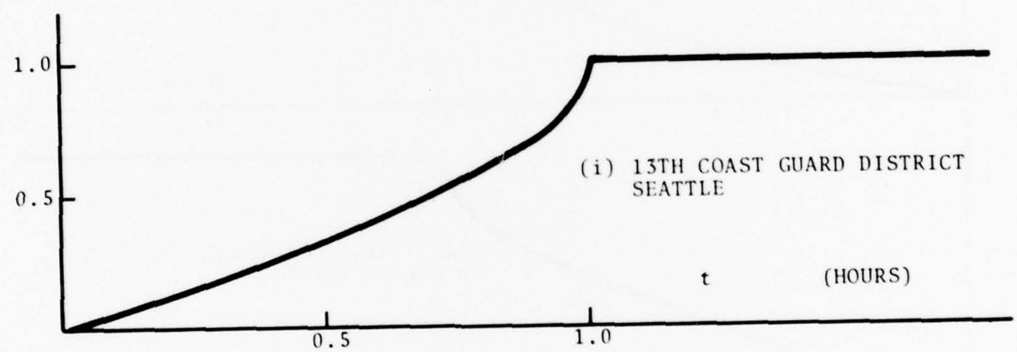

FIGURE H-3. PROBABILITY OF CUTTER AVAILABILITY IN t HOURS OR LESS (i)

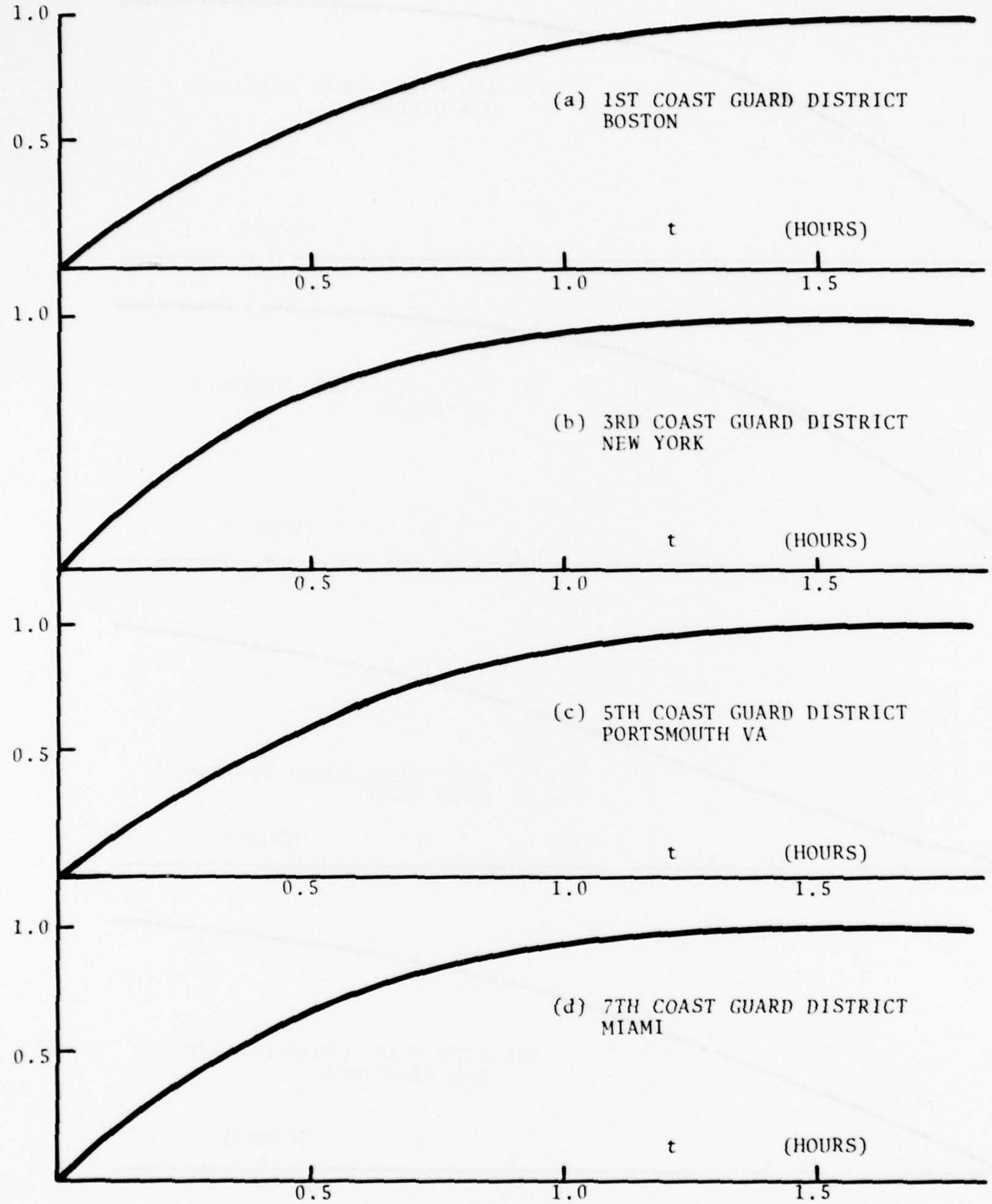

FIGURE H-4. PROBABILITY OF BOAT AVAILABILITY IN t HOURS OR LESS (a-d).

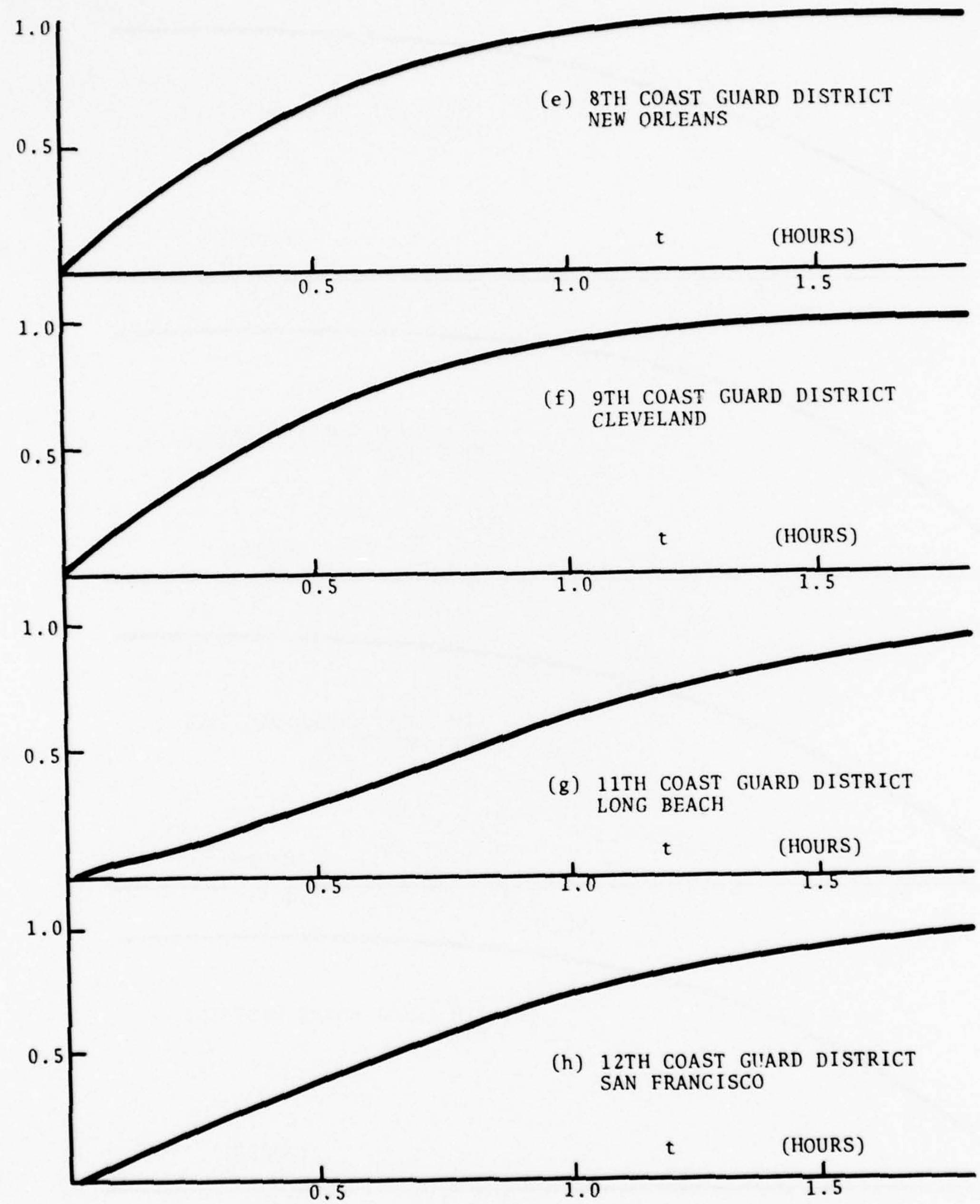

FIGURE H-4. PROBABILITY OF BOAT AVAILABILITY IN t HOURS OR LESS (e-h)

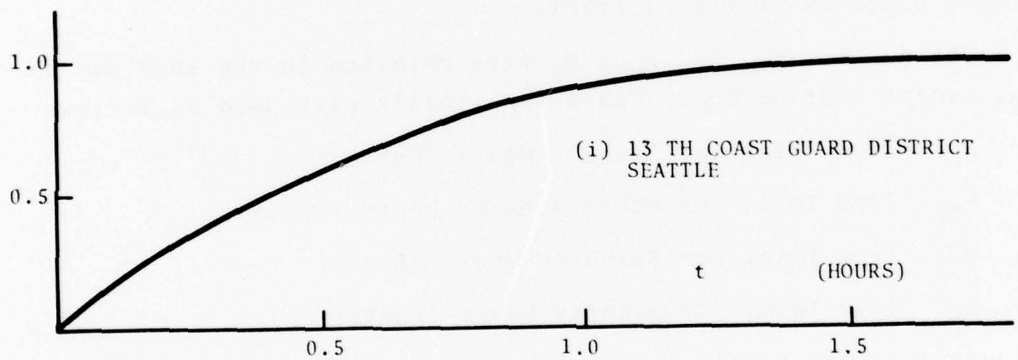

FIGURE H-4. **PROBABILTY OF BOAT AVAILABILTY IN t HOURS OR LESS (i)**

N_{uB} = Average number of boats of given type, speed V, underway at any time in the District

N_S = Average number of boats of given type, on standby status, at any one port of the district.

Note: Port is used above to designate a US Coast Guard coastal station or base.

The number N_{uC} is obtained from the Abstract of Operations by taking the resource hours* of the US Coast Guard Type Totals (p 75 ff) by cutter type and multiplying it by the ratio of total District resource hours to total USCG resource hours, for all types of cutters. This procedure was necessary because District resource hour totals by type are not available in the Abstract. The type-specific resource hours, pro rated to the District, is then divided by 8760, the number of hours in 1975, to get average number of cutters underway in the District.

The numbers N_6, N_X, N_{uB}, N_s were obtained in the same way as N_{uC}, except that US Coast Guard Type Totals were used as follows

N_6: Type Total for Standby Hours (Cutters)

N_X: Type Total for Other Standby Hours (Cutters)

N_{uB}: Type Total for Resource Hours (Boats)

N_S: Type Total for Standby Hours (Boats)

The various Type Totals above are shown in Table H-1, along with totals for maintenance and storage. The ratio used to pro-rate to Districts in each case was the ratio of total District hours to total USCG hours for the type of utilization involved (Standby, Other Standby, Storage, Underway, etc.). These data are given in Table H-2.

The vessel speeds and District coastal lengths employed are given in Table H-3. Several approximations were made, in addition to those described above: (1) In order to obtain the number

*A resource hour is synonymous with an underway hour here.

TABLE H-1 USCG VESSEL UTILIZATION FOR FY1975[1] BY TYPE

CUTTERS

Cutter Type	Underway Hours	Bravo-6 Hours	Bravo-X Hours	Maintain Hours
WHEC/327	14,517	1,231	3,015	25,037
WHEC/378	37,023	1,881	12,395	53,823
WMEC/210	37,522	36,230	26,635	39,852
WMEC/213	1,581	4,803	280	2,095
WMEC/205	3,919	10,433	671	11,256
WMEC/143	3,900	9,070	0	4,550
WMEC/-	2,912	2,102	1,049	2,697
WPB/95	15,047	116,558	16,577	46,713
WPB/82	41,333	276,283	44,735	101,923
WLB/180	47,819	75,414	78,068	72,695
WLM/177	5,313	4,139	15,648	9,940
WLM/157	5,104	15,151	13,426	10,119
WLM/133	6,948	15,480	24,124	14,768
WLI/100[2]	7,015	12,094	21,912	13,747
WLI/100[2]	1,425	41	13,527	2,527
WLI/74	3,219	4,356	6,694	3,251
WLI/65	4,983	16,647	20,802	10,128
WYTM/110	9,130	57,835	13,896	33,019
WYTL/65	13,633	40,292	49,866	27,609
WYTM/UNK	219	0	8,507	34

BOATS

Boat Type	Underway Hours	Standby Hours	Maintain. Hours	Storage Hours
BU/40	727	9,740	637	6,008
BU/45	9,758	115,414	17,065	19,883
MLB/41	42,909	702,834	125,180	46,216
MLB/52	1,333	30,434	5,481	0
UTB/40	69,099	864,567	214,174	251,605
OTH/>40[4]	48,199	385,408	79,887	38,435

(1) Source: Reference H-1.
(2) The Reference has two entries for WLI/100.
(3) Total Accounting hours for the type is the sum of the four entries on the line.
(4) Type not specified. Apparently includes such types as ANB/65, BUSL/46, UTB/41, Bu/52.

TABLE H-2 VESSEL UTILIZATION FOR FY1975[1] BY DISTRICT[2]

CUTTERS

District No.	Underway Hours	Bravo-6 Hours	Bravo-X Hours	Maintain. Hours
1	39,239	56,360	68,060	72,861
3	35,916	95,240	54,817	85,767
5	28,967	100,864	21,540	70,873
7	38,968	91,155	73,825	61,059
8	36,511	95,514	59,248	54,007
9	17,133	51,812	24,337	29,380
11	24,035	65,669	4,129	22,255
12	18,540	70,029	10,546	32,285
13	27,256	42,695	47,483	45,755
14	10,458	9,865	13,998	25,759
17	22,807	57,225	14,606	32,621
	299,830	736,428	392,589	532,622

BOATS

District No	Underway Hours	Standby Hours	Maintain. Hours	Storage Hours
1	34,127	639,853	132,996	362,832
3	48,793	884,753	214,042	247,436
5	35,846	714,281	106,267	66,281
7	42,706	701,652	153,851	119,965
8	41,685	877,840	110,176	135,322
9	37,960	1,192,138	70,481	580,914
11	12,934	176,022	45,470	80,696
12	18,291	378,915	48,007	72,077
13	36,324	590,334	83,109	350,071
14	4,750	65,477	20,561	22,975
17	4,467	46,304	11,365	18,321
	317,883	6,267,569	996,325	2,056,890

(1) Source: Reference H-1.

(2) The 2nd District was excluded because a large number of the vessels in that District have been excluded from our vessel list. The vessels of Table H-1 are predominantly coastal vessels. Headquarters utilization has been excluded for the same reason.

TABLE H-3 USCG CUTTER AND BOAT SPEEDS USCG DISTRICT COASTAL LENGTHS

Vessel Type	Max Speed, V	District	Distance, D[1]
CUTTERS			
WHEC/327	28 knots	1	925 n.mi.
WHEC/378	28	3	525
WMEC/210	16	5	600
WMEC/213	16	7	1100
WMEC/205	16	8	1100
WMEC/143	16	9	2500
WMEC/-	16	11	250
WPB/95	20	12	650
WPB/82	24	13	700
WLB/180	13		
WLM/177	12		
WML/157	13		
WLM/133	10		
WLI/100	10		
WLI/100	10		
WLI/74	10		
WLI/65	10		
WYTM/110	10		
WYTL/65	10		
WYTM/UNK	10		
BOATS			
BU/40	10		
BU/45	10		
MLB/44	14		
MLB/52	11		
UTB/40	26		
OTH/>40	15		

(1) Approximate length of coast when traversed, at about 25 miles from shore.

of vessels on standby at the FSD site, the numbers of standby vessels N_6, N_x and N_S were divided by the number of Coast Guard installations in the District at which the vessels are stationed (Reference H-2. The assumption implicit here is the fact that the waterborne sleds will be stationed with equal likelihood at such USCG installations. This assumption is good except where there are only one or two installations in the District that harbor the specific vessel type. To compensate for those few cases, the number of installations in a District having a specific vessel type was incremented by one. (2) The length of coastline D, patrolled was taken to be 100 n.mi. for small buoy tenders (WLI/74 and WLI/65), 50 n.mi. for all the boats, and 10 n.mi. for harbor tugs; the values of Table 7-C.3 were used in all other cases.

RESULTS

The probability $P_C(t)$ that one or more cutters will be available at the equipment site in t hours or less is plotted in Figures H-3 (a) through (i) for Districts 1 through 13. Similarly, the probabilities $P_B(t)$ for boats is plotted in Figure H-4 (a) through (i). The probability that either a cutter or a boat is available in t hours or less is $1 - (1 - P_C(t)) . (1 - P_B(t))$.

The curves shown in Figure H-3 indicate that a cutter is always available in one hour or less at all storage sites. However, this conclusion rests on the somewhat arbitrary assumption that Coast Guard harbor tugs (WYTM's and WYTL's) are among the available ocean-going cutters. If these tugs are assumed to operate over a range of 10 n. miles from each site and to have a maximum speed of 10 knots, it follows that one of them should always be available within one hour, regardless of the availability of other large vessels. Although these are reasonable assumptions for many East and Gulf Coast ports, they are not valid for the West Coast since no CG tugs are stationed there. For this reason the cutter availability curves for the 11th, 12th and 13th Districts (Figure H-3) do not represent the actual situation at West Coast ports.

It can be concluded from this analysis that while there is a high probability of a boat being available within one hour, the corresponding probability for cutters is more difficult to estimate using the present method. An accurate estimate of cutter availability can be obtained only by a port-by-port analysis using actual vessel assignments for data and models tailored to each control area.

REFERENCES FOR APPENDIX H

H-1. U.S. Department of Transportation, Transportation Computer Center, Report No. 04595Q, Abstract of Operations Fiscal Year 1975, September 30, 1975. 2 Vols.

H-2. U.S. Coast Guard SAF Facility Location Booklet, published by FLAG PLOT for use in conjunction with morning operations highlights, current as of 1 July 1977.

APPENDIX I:

COAST GUARD AND DOD AIR BASES

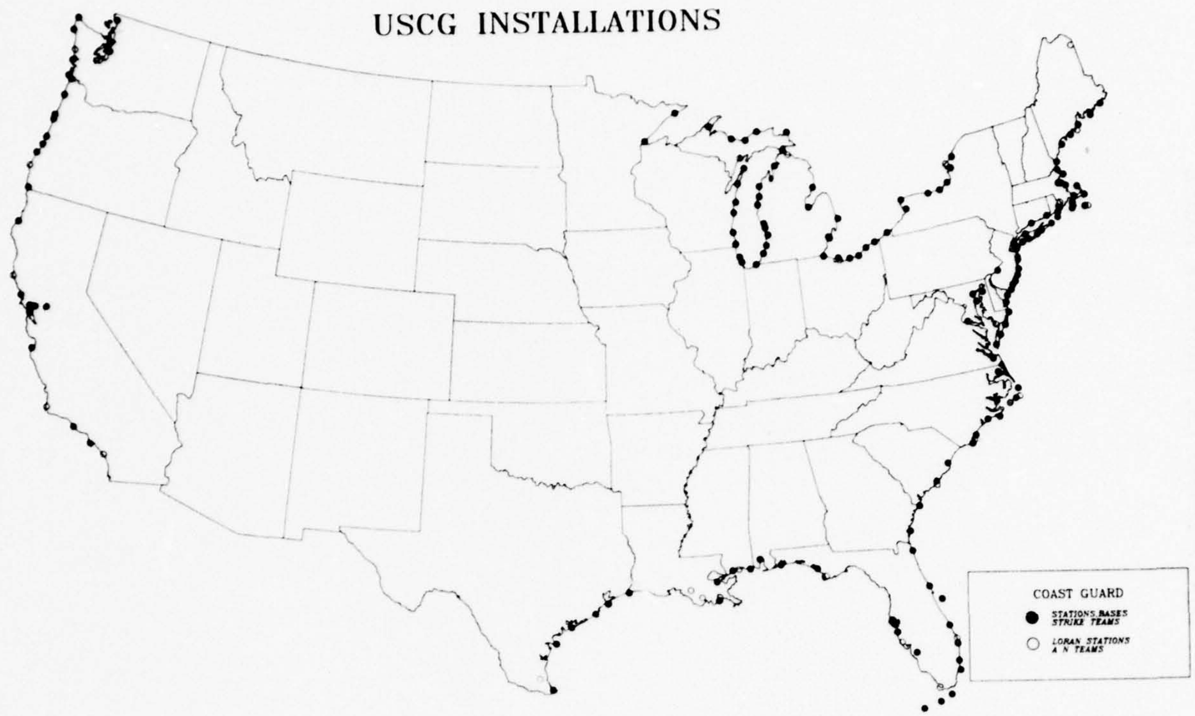

FIGURE I-1 U.S. COAST GUARD BASES, STATIONS, A/N STATIONS AND LORAN STATIONS IN THE 48 STATES

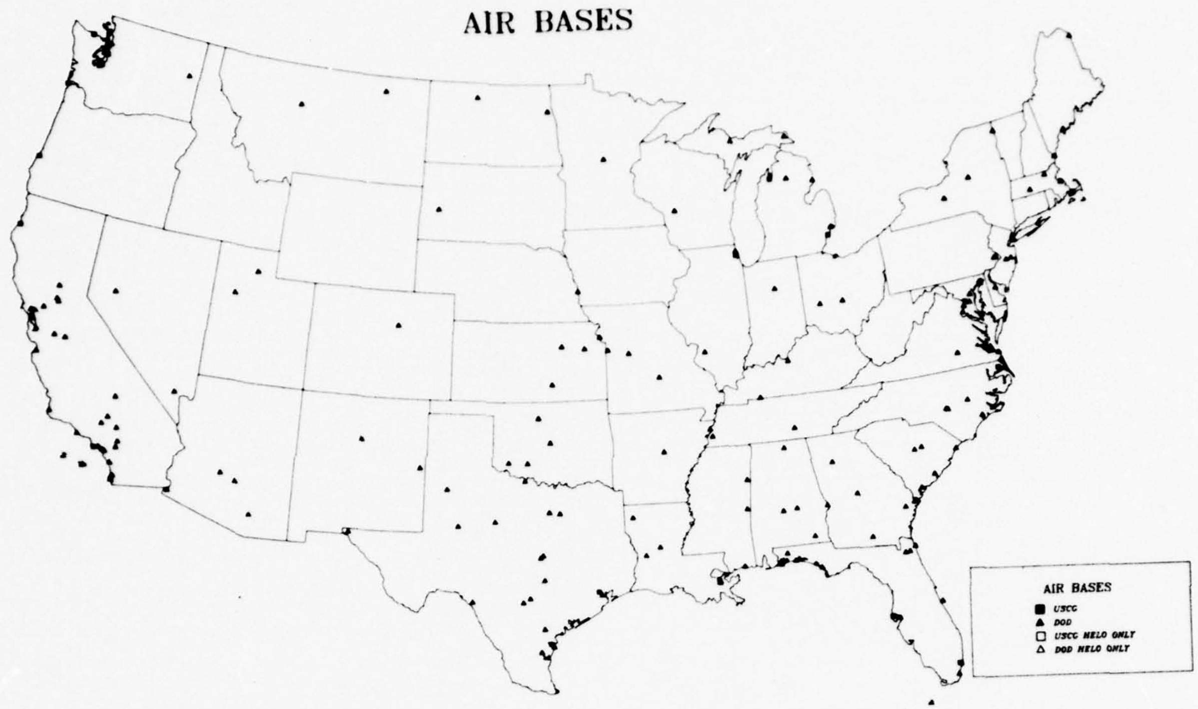

FIGURE I-2 USCG AND DOD AIR BASES IN THE 48 STATES

APPENDIX J:

SPILL POTENTIAL DATA BASE

The spill potential data base was assembled from (1) the U.S. Army Corp. of Engineer's "Waterborne Commerce of the United States", 1976, (2) USGS estimates of future OCS leases and data on current (1977) OCS production, and (3) spill rates obtained in Section 3 of this report.

1. ACOE PORT OIL MOVEMENT

Reference J-1 contains ACOE CY 1976 data on domestic waterborne petroleum movements, plus Bureau of the Census data on oil imports and exports. The data are classified by

(1) Waterway, channel, or port

(2) Type of petroleum or product

(3) Type of traffic.

Selection of data was made, based on these three classifications, so as to most nearly represent the oil movement of concern to the study. The selection was based on the following criteria.

(1) Waterway, channel or port: The ACOE data represents oil movements, rather than oil landed or shipped. This is not inappropriate to the estimation of spill potential, since many spills occur in passage through channels due to groundings, collisions and rammings. However the study area does not encompass movements on the Mississippi River System above Baton Rouge, the Intracoastal waterways, and inland lakes and rivers, except the Great Lakes. In addition, many coastal rivers and creeks carry almost insignificant amounts of petroleum, mainly light oils, and can be ignored. A complete list of exclusions from Parts 1 through 4 of Reference J-1 is given at the end of this Appendix. All other movements of the 1976 ACOE data were included in the spill potential data base. Exclusions of over 1,000,000 tons of petroleum/year are noted in the list, as well as exclusions of

between 100,000 and 1,000,000 tons/year. All other exclusions are less than 100,000 tons.

(2) <u>Type of petroleum or product</u>

Data were tabulated for two general categories of petroleum using the following ACOE type codes

a. Heavy and Crude, comprising:

1311 Crude Petroleum
2915 Residual fuel oil
2916 Lubricating oils and greases

b. Light Oils, comprising:

2911 Gasoline, including natural gasoline
2912 Jet fuel
2913 Kerosene
2914 Distillate fuel oil
2917 Naphtha, mineral spirits, solvents,

(3) <u>Type of Traffic</u>

The ACOE and Bureau of Census traffic at ports is classified as:

a. Imports
b. Exports
c. Coastal Receipts
d. Coastal Shipments
e. Internal Receipts
f. Internal Shipments
g. Lakewise Receipts
h. Lakewise Shipments
i. Local
j. Intraterritorial Receipts
k. Intraterritorial Shipments

River, channel and Waterway Traffic is classified as above, or as:

l. Upbound
m. Downbound

n. Inbound

o. Outbound

p. Through.

These categories were extracted separately (for the waterways and petroleum types of (1) and (2)) and then grouped as follows:

Group 1, Coastal and Foreign, comprising types a,b,c,d,g,h, j, k, n, o

Group 2, Internal and Local, comprising types e,f,i,l,m,p.

Traffic at some of the smaller ports is broken down by petroleum type (2) but not by traffic type (3). They are listed simply as total tonnage. Such totals were classified as Group 2.

2. ESTIMATES OF OCS PRODUCTION

The expected total reserves and production life of East Coast, Gulf Coast and West Coast OCS areas were extracted from References 3-8, 3-9, 3-10, 3-11, 3-13, and J-2, and estimates for 1985 made as follows (Table J-1).

For future well fields the annual production shown was assumed to be distributed evenly over

13 well fields in Georges Bank
4 well fields in Baltimore Canyon
8 well fields in South East Georgia Embayment
14 well fields in Eastern & Western Gulf
6 well fields in Southern California.

based on the number of lease sites planned. Their geographic distribution was as shown in Section 3, Figures 3-19, 3-20, 3-21, 3-22, 3-23, and 3-24. The present well fields were assumed to continue to produce, although both a shift in location and production level is likely. Nevertheless the existing sites, and production shown in the Table were taken as an approximation to the situation in 1985 with regard to present wellfields. Their locations were extracted from Reference J-2 and inserted into the spill potential data base. The estimated total reserves of the present fields were also extracted from reference J-2 and

TABLE J-1: ESTIMATED 1985 ANNUAL OCS PRODUCTION (TONS)

L LOCATION	RESERVES TOTAL	YEARS LIFE	ANNUAL PRODUCTION	REFERENCE
Georges Bank (1)*	$68. \times 10^6$	25	3.1×10^6	3.8
Baltimore Canyon (1)	135.	25	5.4	3.9
S.E. Georgia (1)	90.	25	3.6	3.10
Eastern Gulf / Western Gulf (1)	10.	25	0.4	3.11
Louisiana (present)	265.1	25	10.5	8-A.2
S. California (1)	85	25	3.4	3.13
S. California (present)	-	-	12.	8-A.2
	960	25	38.4	

*(1) Proposed

TABLE J-2: EXISTING OCS WELL FIELDS[1]

FIELD		LAT/LON[2]	1976 PRODUCTION 10^6 BBL/YR	RESERVES AS OF 1/77 10^6 BBL
Louisiana				
Bay Marchand	Blk 2	2905/9010	22	176
Eugene I.	Blk 330	2840/9142	31	132
Eugene I.	Blk 276	2849/9133	3	111
Grand I.	Blk 16	2903/8955	8	119
Grand I.	Blk 43	2900/8950	15	174
Main Pass	Blk 41	2924/8900	1	120
Main Pass	Blk 69	2915/8905	5	58
Ship Shore	Blk 207	2832/9105	6	119
South Pass	Blk 24	2900/8920	11	95
South Pass	Blk 27	2855/8925	6	111
South Pass	Blk 62	2900/8900	4	132
South Pass	Blk 65	2900/8900	7	128
Timbalier Bay	Blk 30	2401/9016	2	92
West Delta	Blk 30	2910/8936	17	103
West Delta	Blk 73	2855/8945	10	143
West Delta	Blk 58	2900/8950	8	130
Southern California				
Dos Cuadros		3420/11935	12	93
Santa Ynez		3418/12022	0	-
Huntington Beach		3340/11805	15	120
Wilmington		3346/11811	60	610

(1) Source: Reference J-2

(2) Approximate only.

pro-rated over a 25 year period to get the annual production shown in Table J-1 which averages about half of present production.

The present wellfields are listed in Table J-2.

3. SPILL RATES

The spill rates for port oil movements and OCS production were calculated in Section 3 of this report. The spill rates for transient tankers, deepwater ports and lightering were found to be an order of magnitude less than those for port movements and the OCS, and hence were not included in the data base. The port and OCS spill rates employed are as follows (spills per million tons):

Port Movement

Greater New York	.0212
Delaware Bay	.0627
Louisiana Coast	.0682
North Texas Coast	.0193
All other areas	.0314

OCS Production

All fields	.0271

The annual oil movement and production tonnages projected from the sources cited above were multiplied by these spill rates to obtain the spill potential data base.

4. LIST OF PORTS AND WATERWAYS FROM REF. J-1 EXCLUDED FROM SPILL POTENTIAL DATA BASE

* indicates 100,000 to 1,000,000 tons/year; ** indicates over 1,000,000 tons of petroleum/year.

PART 1

** 1. Federal Lock; Troy, N.Y.

** 2. New York State Barge Canal System, NY

** 3. Narrows of Lake Champlain, NY and VT

PART 1 (Cont'd)

* 4. Burlington Harbor, VT

* 5. Plattsburgh, NY

** 6. Inland Waterway from Delaware R. to Chesapeake Bay-
Chesapeake and Delaware Canal

* 7. Mantua Creek, N.J.

* 8. Big Timber Creek, N.J.

9. Cohansey River, N.J.

10. Oldman's Creek, N.J.

11. Cooper River, N.J.

12. Chaptank River, N.J.

13. Warwick River, MD

* 14. Atlantic Intracoastal Waterway Between Norfolk, Va and the St. John's River, Fla. (Norfolk District) via Great Bridge Loch Route.

* 15. Roanoke River, N.C. (Albermarly Sound, Plymouth, NC)

16. Pamlico and Tar Rivers, N.C.

17. Neuse River, NC

18. Atlantic Intracoastal Waterway between Norfolk VA and the St. John's River, Fla. (Wilmington District)

19. Cape Fear River, (except Wilmington Harbor), NC

* 20. Cape Fear River above Wilmington

* 21. Northeast Cape Fear River

22. Smith's Greek (Pamlico County) NC

* 23. Atlantic Intracoastal Waterway between Norfolk VA and the St. John's River (Charleston District)

24. Atlantic Intracoastal Waterway between Norfolk Va and the St. John's River, Fla (Savannah District)

25. Satilla River, Ga.

* 26. Savannah River below Augusta, Ga.

* 27. Atlantic Intra coastal Waterway between Norfolk, Va and the St. John's River, Fla. (Jacksonville District)

** 28. St Johns River Fla, Jacksonville to Lake Harney

** 29. Intra coastal Waterway, Jacksonville to Miami, Fla.

30. Intra coastal Waterway, Miami to Key West, Fla.

*30.5 Rice Creek Fla.

PART 1 (Cont'd)

31. Canapitsit Channel MA
32. Cross Rip Shoals, Nantucket MA

PART 2

* 1. Vicksburg, Miss., District
2. Memphis, Tenn., District
3. St. Louis, MO., District
4. St Paul, Minn., District
** 5. Little Rock, Arkansas, District
* 6. Missouri River Division,
* 7. Nashville, Tenn., District
8. Lousiville, KY, District
* 9. Huntington, W. Va., District
** 10. Pittsburgh, Pa., District
** 11. Ohio River Division
** 12. Gulf Intracoastal Waterway (Applachee Bay to Mexico) (Between Apalachee Bay, Fla., and the Mexican Border)
* 13. Intracoastal Waterway, Caloosahatchee River to Anclote River Fla.
* 14. Black Warrior and Tombigbee Rivers, Ala.
* 14.5 La Grange Bayou Fla.
15. Mississippi River - Gulf Outlet, La.
16. Waterway from Empire, La., to Gulf of Mexico
17. Barataria Bay Waterway, La.
* 18. Bayou Lafourche and Lafourche - Jump Waterway, La.
19. Bayou Terrebonne, La.
* 20. Bayou Little Caillou, La.
** 21. Houna Navigation Caval, La.
22. Waterway from Intracoastal Waterway to Bayou Dulac, La.
** 23. Mississippi River (Except Baton Rouge, and New Orleans)
** 24. Atchafalaya River, La. above Morgan City, La.
* 25. Red River below Fulton, Ark.
** 26. Gulf Intracoastal Waterway, Morgan City - Port Allen Route
27. Petit Anse, Tigre and Carlin Bayous, La.

PART 2 (Cont'd)

** 28. Lake Charles Deep Water Channel Intracoastal Waterway, La.

29. Bayou Teche, La.

30. Mermentau River, La.

31. Bayou Teche and Vermillion River, La.

* 32. Mermentau River, Bayous Nezpique and Des Cannes, La.

33. Bayous: Dupre, Segnette Waterway, La. Loutre, St. Malo, vs Closkey, Big Pigeon, Little Pigeon.

34. Chefuncta and Bogue Falia Rivers, Franklin Canal, Fresh water Bayou, Vinton Waterway,

35. Lake Pontchartrain

* 36. Johnson's Bayou

** 37. Chocolate Bayou, Tex.

* 38. San Bernard River, Tex.

39. Colorado River and Flood Discharge Channels, Tex.

* 40. Tributary Arroyo Colorado, Tex.

41. Port Mansfield, Tex.

42. Chicago, Ill. District. (Port of Chicago is tabulated)

43. Blackwater River, Fla.

44. Gulf County Canal, Fla.

45. La Grange Bayou, Fla.

PART 3

** 1. Illinois River, Illinois Waterway

2. St. Marys River, Mich

3. St. Clair River, Mich,

* 4. Channels in Lake St. Claire

** 5. Detroit River, Mich. (includes port of Detroit, which is tabulated)

* 6. Gray's Reef Passage, Mich (all through)

7. Sturgeon Bay and Lake Michigan Ship Canal (through)

PART 4

** 1. Through Traffic in San Pablo Bay & Mare Island Strait (St. Joaquin River and Stockton are included)

** 2. Through Traffic in Carquiny Strait, and Suisan Bay Channel

* 3. Columbia River and Tributaries above McNary Loch & Dam

* 4. Snake River, Oreg. and Idaho.

** 5. Columbia River and Willamette River except Astoria, St. Helens, Longview, Vancouver Kalama, Portland, and other ports on Columbia and Willamette up to McNary Loch & Dam

6. Clatskanie River, Oreg.

7. Hoquiam River, Wash.

8. Waterway connecting Port Townsend Bay and Oak Bay, Wash.

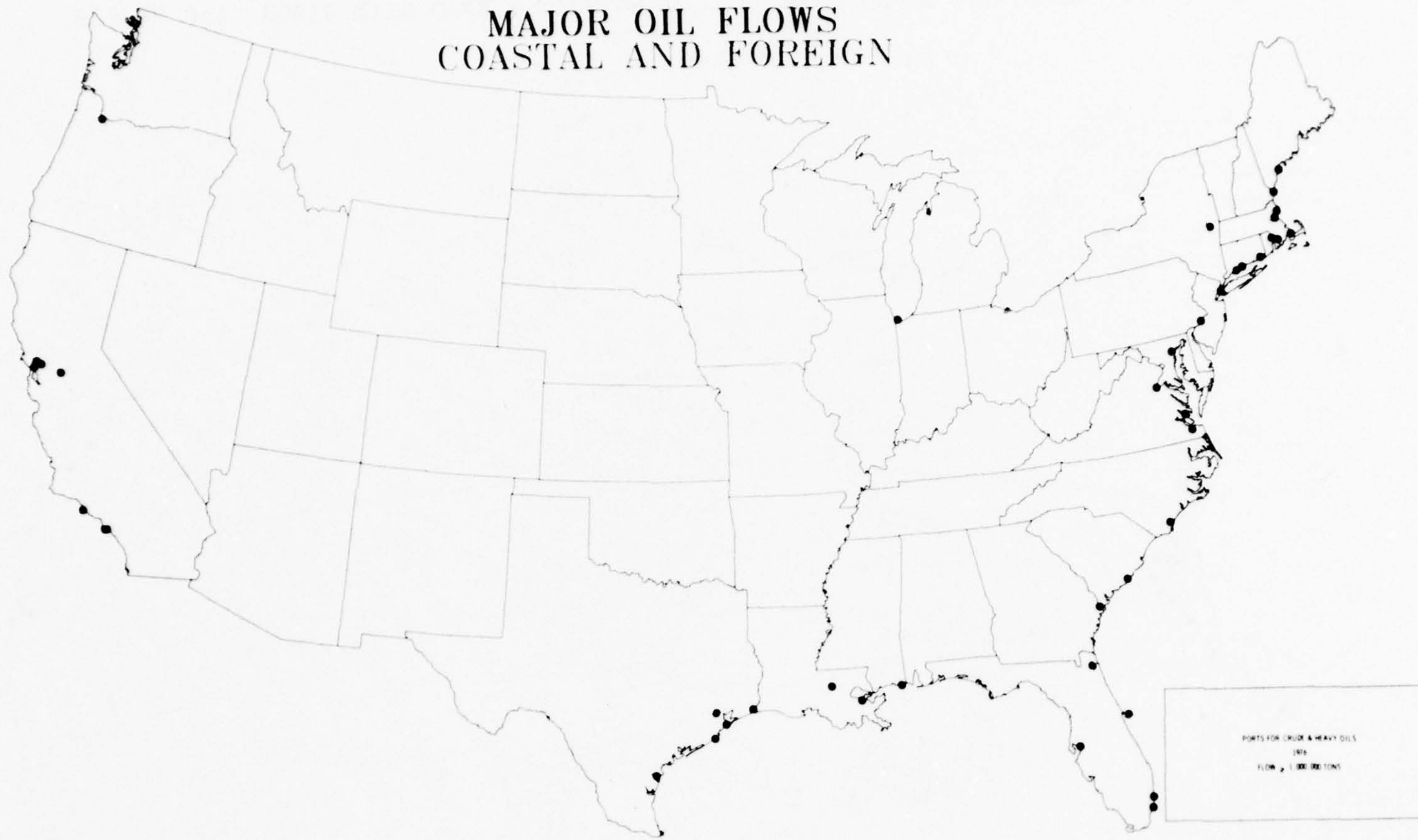

FIGURE J-1 PORTS WITH OVER 1 MILLION TONS FLOW OF CRUDE AND HEAVY OILS IN 1976 (COASTAL AND FOREIGN)

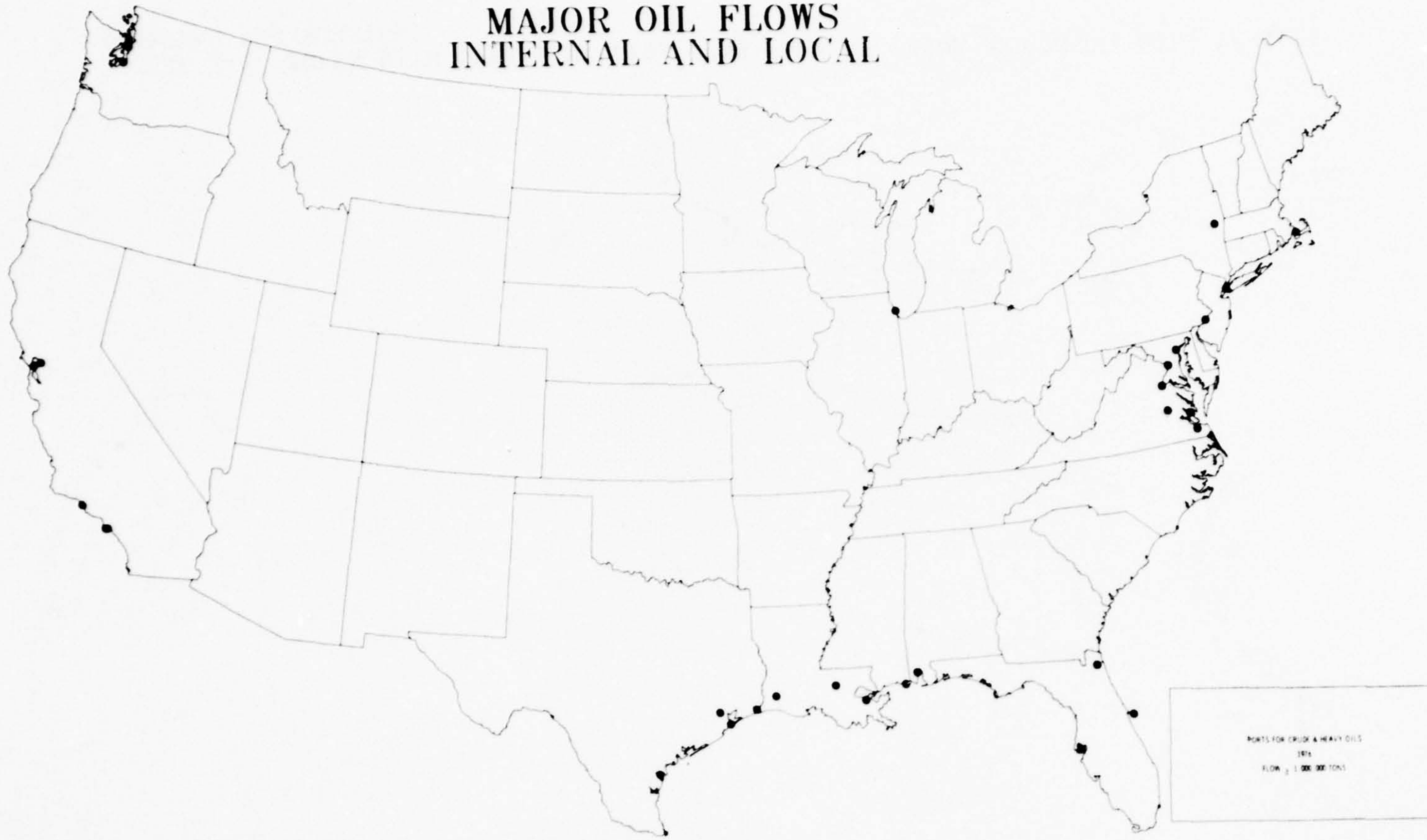

FIGURE J-2 PORTS WITH OVER 1 MILLION TONS FLOW OF CRUDE AND HEAVY OILS IN 1976 (INTERNAL AND LOCAL)

MAJOR OIL FLOWS
COASTAL AND FOREIGN

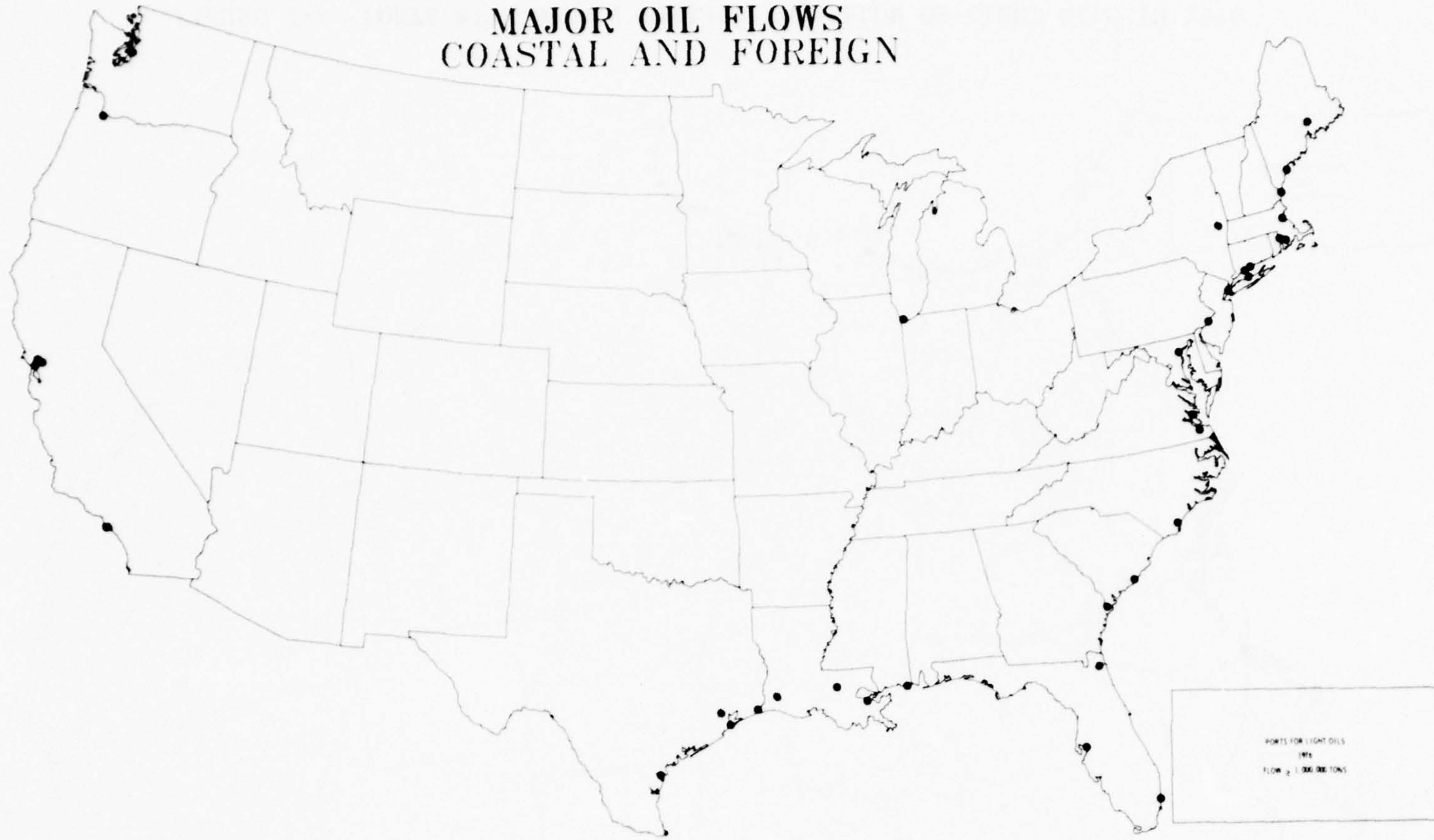

FIGURE J-3 PORTS WITH OVER 1 MILLION TONS FLOW OF LIGHT OILS IN 1976
(COASTAL AND FOREIGN)

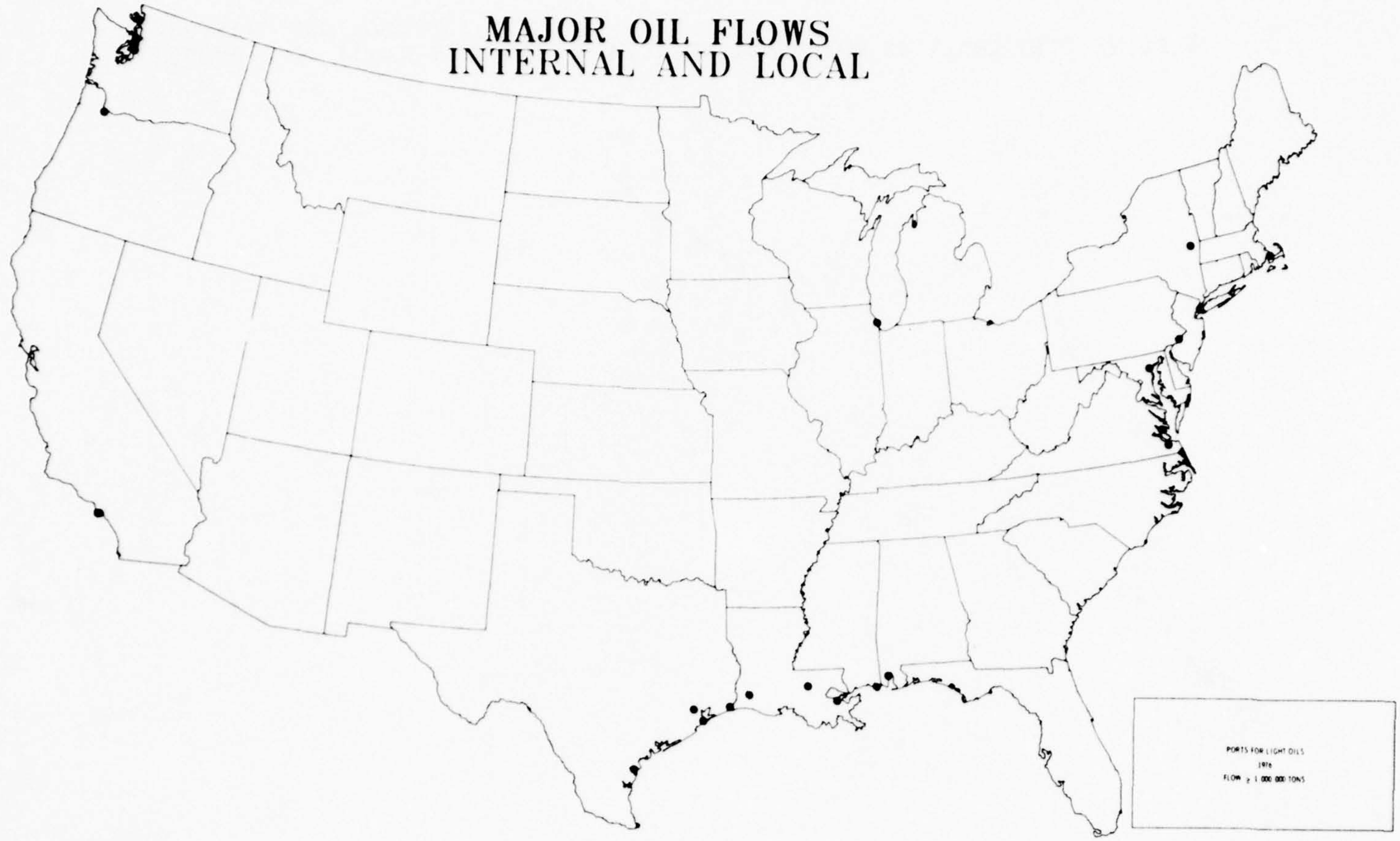

FIGURE J-4 PORTS WITH OVER 1 MILLION TONS FLOW OF LIGHT OILS IN 1976 (INTERNAL AND LOCAL)

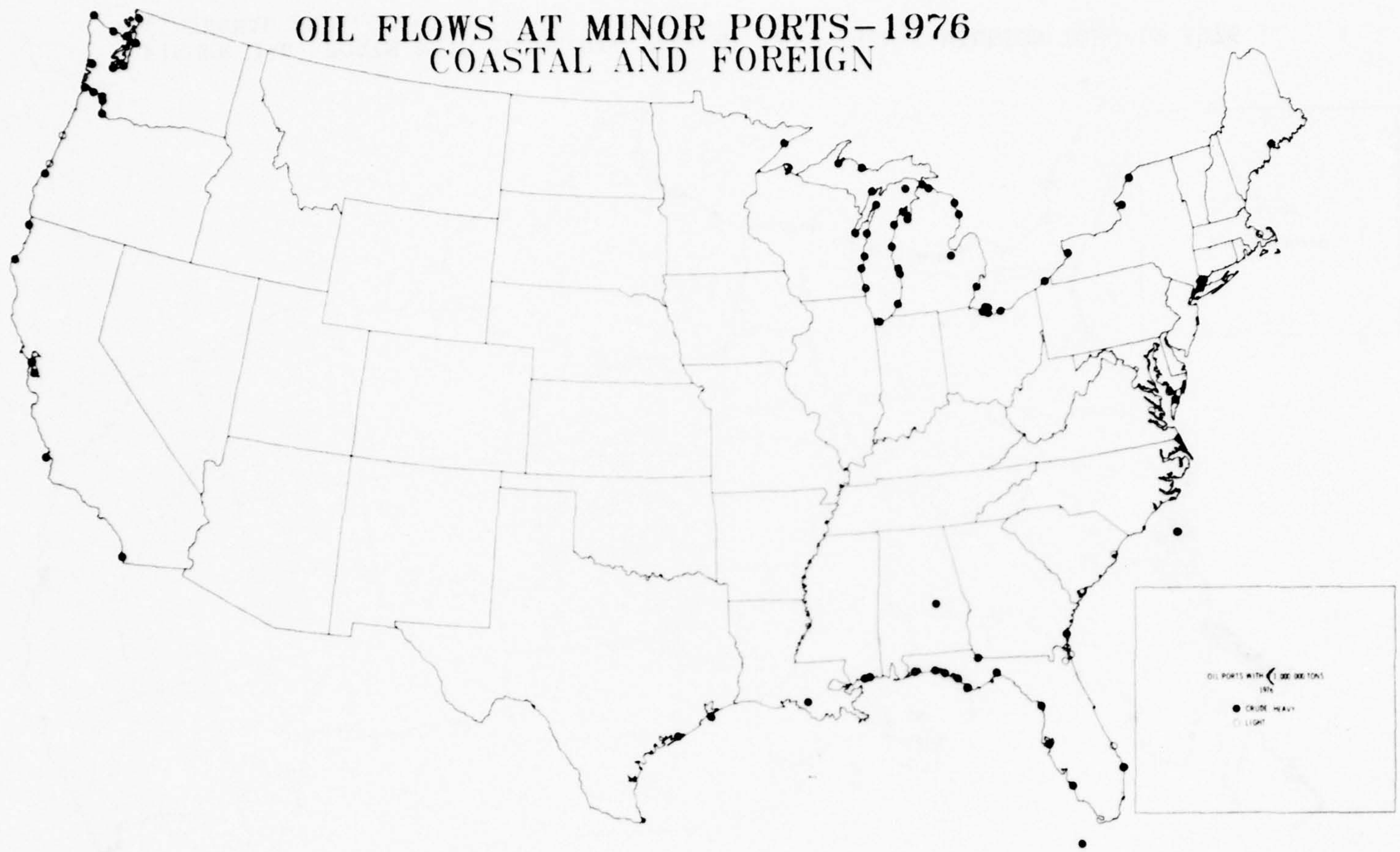

FIGURE J-5 PORTS WITH TOTAL OIL FLOW OF LESS THAN 1 MILLION TONS IN 1976
(COASTAL AND FOREIGN)

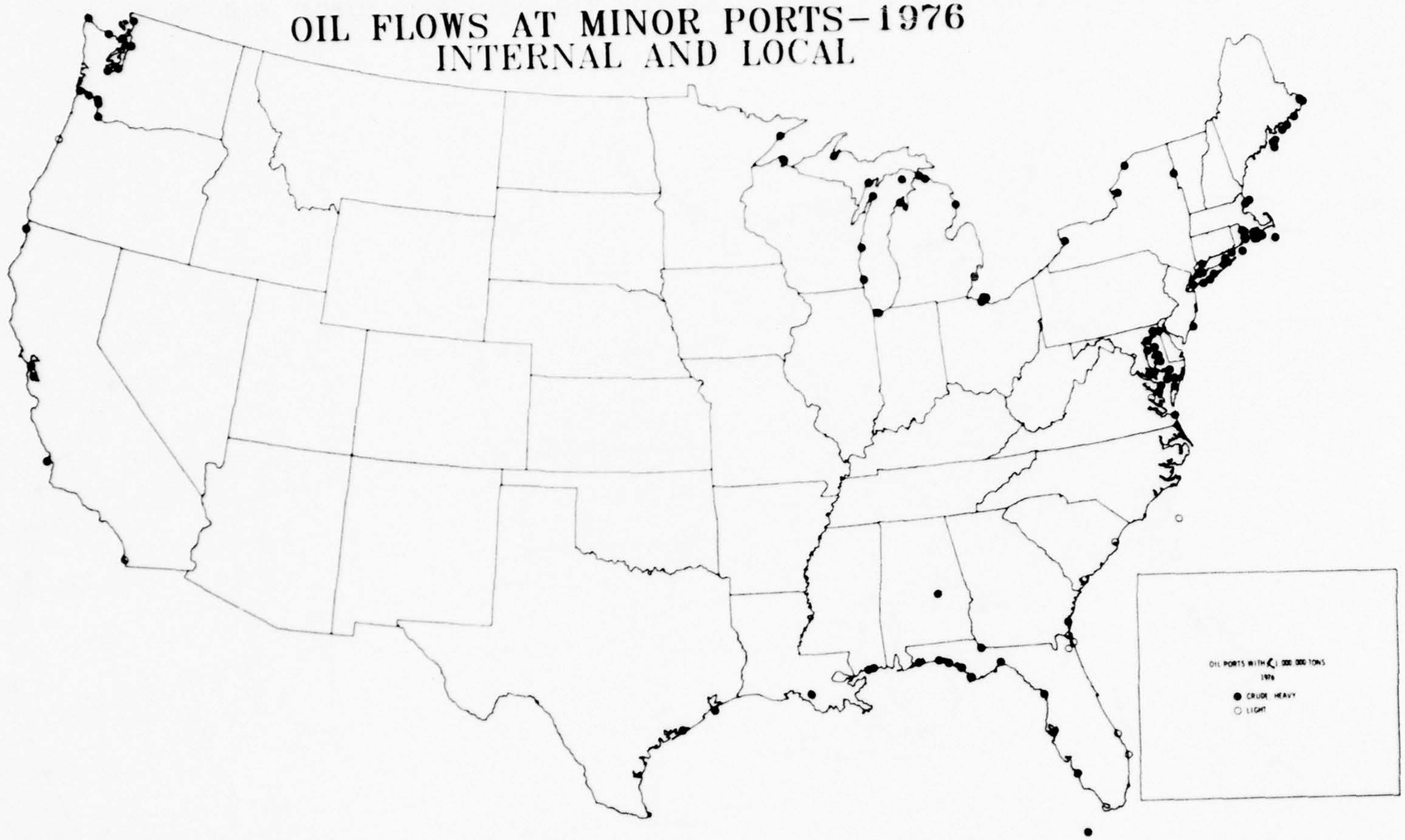

FIGURE J-6 PORTS WITH TOTAL OIL FLOW OF LESS THAN 1 MILLION TONS IN 1976 (INTERNAL AND LOCAL)

REFERENCES FOR APPENDIX J.

J-1. Department of the Army, Corps of Engineers, "Waterborne Commerce of the United States", Calendar Year 1976, Parts 1 through 4.

J-2. International Petroleum Encyclopedia, 1977, Vol. 10, The Petroleum Publishing Co., Tulsa, OK. 74101.

APPENDIX K

POLLUTION RESPONSE ALLOCATION MODEL

This Appendix derives the optimum levels of oil pollution recovery capability to be allocated to each of N equipment storage sites when the total capability is limited. The i^{th} site, $i = 1,2,3,\ldots,N$, is to be assigned an amount of equipment with oil recovery capability s_i, measured in gallons, which will be brought to bear upon any spill that occurs in the geographic region served by that equipment site. The major assumptions are:

1. The regions do not overlap.
2. Spills occur one at a time.
3. The distributions of the number and volume of spills in a year are independent and are known for each region.
4. The amount of oil recovered at a spill is no greater than the recovery capability s_i of the region in which it occurs, plus a fraction a_{ij} of the capability of each other site j. Symbolically,

   $$r_i = \sum_{j=1}^{N} a_{ij} s_j$$

   where r_i is the maximum amount of oil recovered at a spill in region i. (Note that $a_{ii}=1$.)
5. The total capability $\sum_{i=1}^{N} s_i$ is limited.
6. The optimum deployment is that which maximizes the expected value of the total amount of oil recovered from all spills.

With the above assumptions, the problem is to assign the site capabilities s_i so as to maximize the amount of oil recovered in a year, subject to the equipment limit 5. and the assistance from

region to region as assumed in 4. To do so, it is necessary first to devise a model for the recovery operation, as follows:

If the amount of oil spilled in an incident is x, the amount recovered, ρ, is assumed to be

$$\rho = \begin{cases} x \text{ if } x \le r_i \\ r_i \text{ if } x > r_i \end{cases} . \tag{1}$$

This is an elaboration of assumption 4. and is only approximately true. In any spill, no matter how small, some of the oil escapes recovery. A more realistic model is

$$\rho_i(x) = \begin{cases} \alpha x \text{ for } x \le r_i \\ \alpha r_i \text{ if } x > r_i , \end{cases} \tag{2}$$

where α is the fraction of oil recovered on a single spill. Even this model describes the situation poorly since ρ is a random function of x. The important question is how the amount recovered varies from region to region. In that respect both models (1) and (2) embody the reasonable assumption that the amounts recovered differ from region to region only in the limits r_i of recovery capabilities of the regions. Hence, the model (1) will be employed for simplicity.

The above model applies to a single spill in the region. When there are exactly n spills in the region, of sizes x_1, x_2, x_3, ..., x_n, the total amount recovered will be

$$\rho_i(x_1) + \rho_i(x_2) + \rho_i(x_3) + \dots + \rho_i(x_n).$$

The average value of this sum is $\bar{R}_i(n)$:

$$\bar{R}_i(n) = \int_0^\infty dx_1 \int_0^\infty dx_2 \int_0^\infty dx_3 \dots \int_0^\infty dx_n \tag{3}$$

$$\left[\rho_i(x_1) + \rho_i(x_2) + \dots + \rho_i(x_n)\right] f_i(x_1, x_2 \dots, x_n),$$

where f_i $(x_1, x_2, x_3, \dots, x_n)$ is the joint density of the n spill volumes. By assumption 3, the spill volumes x_1, x_2, x_3, ..., x_n are independent of n, and hence of each other, so that

$$f_i(x_1, x_2, \ldots, x_n) = f_i(x_1)\, f_i(x_2) \ldots f_i(x_n),$$

where $f_i(x)$ is the volume distribution of a single spill in region i. When this is substituted into (3), one has

$$\bar{R}_i(n) = \int_0^\infty n\, \rho_i(x) f_i(x)\,dx.$$

Finally, this may be averaged over all possible n, to obtain the expected amount $\bar{R}_i$ recovered in region i:

$$\bar{R}_i = \sum_{n=0}^{\infty} p_i(n)\bar{R}_i(n)$$

$$= \sum_{n=0}^{\infty} n\, p_i(n) \int_0^\infty \rho_i(x) f_i(x)\,dx$$

$$= \bar{n}_i \int_0^\infty \rho_i(x) f_i(x)\,dx \qquad (4)$$

where $p_i(n)$ is the probability of exactly n spills in the region. Substituting (1) for $\rho_i(x)$ gives

$$\bar{R}_i = n_i \left[\int_0^{r_i} x\, f_i(x)\,dx + \int_{r_i}^{\infty} r_i f_i(x)\,dx \right]$$

$$= \bar{n}_i \left[r_i - \int_0^{r_i} F_i(x)\,dx \right]$$

(5)

where $F_i(x)$ is the cumulative distribution of spill volume (corresponding to $f_i(x)$). The last expression is obtained by integration by parts. The total amount recovered has an expected value $\bar{R}$ given by

$$\bar{R} = \sum_{i=1}^{N} \bar{R}_i$$

$$= \sum_{i=1}^{N} \bar{n}_i \left[r_i - \int_0^{r_i} F_i(x)\,dx \right] . \tag{6}$$

There is to be maximized by selection of the s_i values, subject to $s_i \geq 0$, $i=1,2,3,\ldots,N$ and to the constraint:

$$\sum_{i=1}^{N} s_i \leq K, \text{ where } r_i = \sum_{j=1}^{N} a_{ij} s_j \tag{7}$$

Here K is the total capability limit. The equality sign may be assumed without loss of generality.

CASE 1, NO ASSISTANCE

In this case $s_i = r_i$, and the problem may be solved by introduction of a constant λ which is used to multiply the constraint (7), taken as equality, and appending the product to $\bar{R}$, to form the function H:

$$H = \bar{R} + \lambda \left[\sum_{i=1}^{N} r_i - K \right] . \tag{8}$$

The necessary conditions for a maximum (see Reference 1) are:

$$\frac{\partial H}{\partial r_i} = 0, \; i=1, \ldots, N \tag{9}$$

$$\frac{\partial H}{\partial \lambda} = 0, \tag{10}$$

which give

$$\bar{n}_i \left(1 - F_i(r_i)\right) + \lambda = 0 \tag{11}$$

and

$$\sum_{i=1}^{N} r_i = K . \tag{12}$$

These equations may be solved by a simple iterative procedure. From (11) one obtains

$$F_i(r_i) = 1 + \left(\lambda/\bar{n}_i\right) \tag{13}$$

or

$$r_i = F_i^{-1}\left(1 + \frac{\lambda}{\bar{n}}\right) \tag{14}$$

Thus, by choosing λ, the r_i may be obtained from (14), or graphically as shown in Fig. K-1. The sum $\sum_{i=1}^{N} r_i$ is then compared to K to determine if (12) is satisfied. If not, increasing (or decreasing) λ will increase (or decrease) that sum until it equals K. The success of this process derives from the monotony of the cumulative distribution functions $F_i(x)$. In detail, the process is as follows:

1. Select a small, negative value for λ
2. Calculate $1 + \lambda/\bar{n}_i$ for $i = 1, 2, 3, \ldots, N$
3. Find r_i, $i = 1, 2, 3, \ldots, N$ from (14) or graphically
4. Calculate TEST $= \sum_{i=1}^{N} r_i$
5. If TEST $>$ K, decrease λ by a small amount δ, and go to 2. Otherwise, STOP.

Note that $\lambda < 0$ and $\delta > 0$. *Decreasing λ by an amount δ*, in step 5., amounts to replacing λ by $\lambda - \delta$.

When the process terminates the resulting set of response capabilities s_i, $i = 1, 2, 3, \ldots, N$ will be the optimum allocation of the total available capability to the N regions, under the given assumptions, with no assistance among sites.

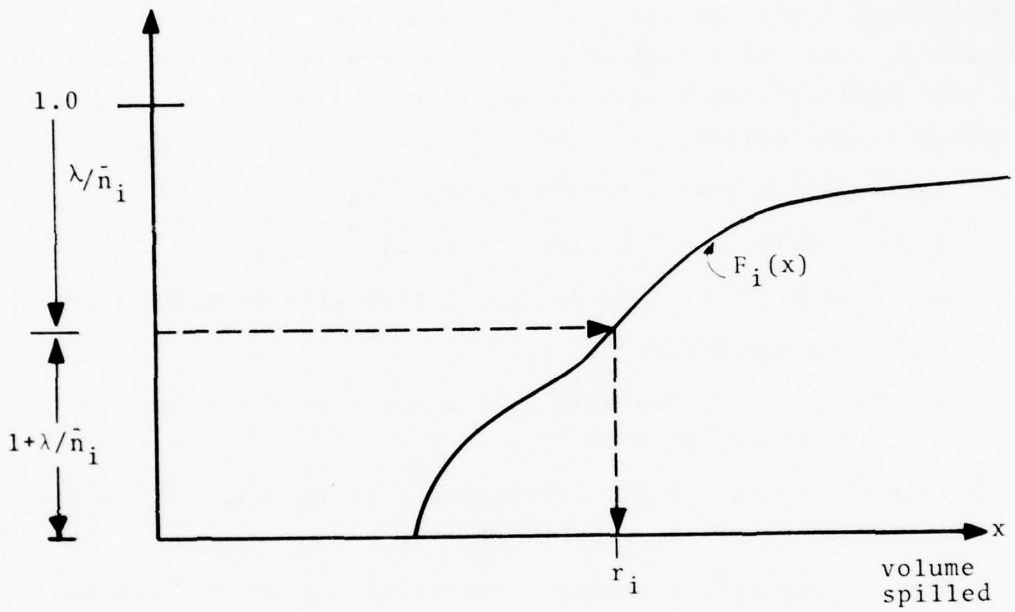

FIGURE K-1 GRAPHICAL SOLUTION OF (14)

CASE 2, ASSISTANCE AMONG SITES

If a fraction a_{ij} of the capability of site j is brought to the assistance of site i, where $i \neq j$, then the matrix a_{ij} is no longer the identity matrix. The above procedure may be employed to obtain the net regional capabilities r_i and then the unassisted site capabilities s_i obtained from (7) by inverting the matrix a_{ij}. But the resulting site capabilities, s_i, are often negative. To avoid such an unrealistic answer it is desirable to select the s_i directly, subject to the constraint $s_i \geq 0$, so that $\overline{R}$ of (6) will be a maximum. The constraint (7) must be satisfied as well. The (assisted) regional capabilities r_i must also be calculated, but only as intermediate quantities because they relate the independent variables s_i to the objective function (6). A slight generalization of this problem replaces the constraints $s_i \geq 0$ by $s_i \geq m_i$, where m_i are given minimum site capabilities.

The problem just described is a common one in mathematical programming. The solution is obtained by a process not unlike that in the previous case. The constraint (7) is multiplied by a constant λ and the constraints $s_i \geq m_i$ are multiplied by constants μ_i. Both products are added to $\overline{R}$ to form the Hamiltonian H:

$$H = \overline{R} + \lambda\left(\sum_{i=1}^{N} s_i - K\right) + \sum_{i=1}^{N} \mu_i \,(s_i - m_i) \tag{15}$$

The necessary conditions for a maximum* are:

$$\frac{\partial H}{\partial \lambda} = \sum_{i=1}^{N} s_i - K = 0 \tag{16}$$

$$\frac{\partial H}{\partial s_i} = \frac{\partial \overline{R}}{\partial s_i} + \lambda + \mu_i = 0 \tag{17}$$

$$\mu_i = 0 \text{ for } s_i > m_i \tag{18}$$

$$\mu_i \geq 0 \text{ for } s_i = m_i \tag{19}$$

*A.E. Bryson and Y-C. Ho, "Applied Optimal Control," Blaisdell Publishing Co., 1969, p. 27.

The sites are divided into two sets; one for which the constraints (18) hold (sites with more than the minimum capability) and one for which the constraints (19) hold (sites with exactly the minimum capability).

A practical procedure for achieving the optimum allocation was devised for this problem without explicit use of the equations (16), (17), (18), (19). It is based on the monotonic nature of the objective function, i.e., increasing any site capability s_i cannot decrease the average total amount recovered, $\overline{R}$. The procedure is as follows:

To start, the total capability K is divided evenly among the N sites. (This is possible provided $K/N \geq m_i$)

Then, the derivatives α_i are calculated:

$$\alpha_i = \frac{\partial \overline{R}}{\partial s_i} = \sum_{i=1}^{N} \overline{n}_i \; a_{ij} \left(1 - F_i(r_i)\right) \qquad (20)$$

Next, the capability s_i is reduced by an incremental amount δ for the site with the minimum α_i, and an equal increment ϵ is added to the site with the largest value of α_i, provided the reduction does not bring s_i below the minimum m_i. This will change $\overline{R}$ by an amount $\delta\overline{R}$, approximately,

$$\delta\overline{R} = \left(\alpha_{max} - \alpha_{min}\right) \delta$$

Finally, the derivatives are recalculated and the process repeated until all sites that are not at their minimum capability have the same value of α.

In effect, this process relocates equipment from sites of lower effectiveness (lower α) to sites of higher effectiveness (higher α). Since equal amounts are added and subtracted at each step, the total capability constraint (16) is always satisfied. At termination, condition (17) is satisfied for all sites: for sites with $s_i > m_i$ (condition (18)), one has $\mu_i = 0$ and therefore

$$\frac{\partial H}{\partial s_i} = \alpha_i + \lambda = 0 \qquad (21)$$

where $\lambda = \alpha_{max}$; for sites with $s_i = m_i$, (condition (19)), one has μ_i such that

$$\frac{\partial H}{\partial s_i} = \alpha_i + \lambda + \mu_i = 0 \qquad (22)$$

It will be observed that λ here is negative, just as in the previous case. In fact, when no site is at its minimum $\mu_i = 0$ for all i and the present case reduces to the previous. As in the previous case, the procedure terminates because as s_i increases α_i generally decreases and $\overline{R}$ increases.

The major difficulty in carrying out the procedure is selecting the step size δ. It was found that a second-order gradient (Newton-Raphson) technique worked satisfactorily for about 20 sites, provided the step was limited to about 0.1 K/N. Specifically, δ was calculated as

$$\delta = \underset{\text{of}}{\text{min}} \begin{cases} K/10N \\ (\overline{\alpha} - \alpha_{min})/\beta_{min} \\ (\alpha_{max} - \overline{\alpha})/\beta_{max} \\ s_i - m_i \end{cases} \qquad (23)$$

where

$$\overline{\alpha} = \sum_{i=1}^{N} \alpha_i/N \qquad (24)$$

$$\beta_i = - \partial\alpha_i/\partial s_i$$

$$= \sum_{i=1}^{N} \overline{n}_j \, \alpha_{ji}^2 \, f_j(r_j) \qquad (25)$$

The subscripts max or min indicate the values of i for which $s_i > m_i$ and α_i is maximum or minimum.

APPENDIX L:
SPILL PROBABILITY MODELS

1. PROBABILITY OF LARGE SPILLS - GENERAL DISTRIBUTION

In this section we derive the probability that in any one year one or more oil spills in U.S. waters will be larger than x gallons in magnitude. The result, $P(x)$, will turn out to be

$$P(x) = \bar{n}(1 - F(x)), \tag{1}$$

where $\bar{n}$ is the average number of spills per year in U.S. waters, and $F(x)$ is the probability of a spill being x gallons or less. The approximation is good if x represents a large spill, i.e., one large enough so that $F(x)$ is close to 1. More precisely, the error E in the approximation is about

$$f^2 \left(\sigma^2 + (\bar{n})^2 - \bar{n}\right)/2, \tag{2}$$

where $f = 1-F(x)$ and σ^2 is the variance of n.

Two observations may be made regarding this result.

Observation 1. The estimate depends on the distribution $F(x)$ of spill size, but on only the mean $\bar{n}$ of the distribution of the number of spills. As will be seen in its derivation, the estimate is valid whether or not the spill number is distributed according to Poisson, Negative Binomial, or other law, as long as the mean and variance of the number of spills are known.

Observation 2. The error (2) may be substantial, relative to the estimate (1), if $\bar{n}$ is more than, say, 10.0 and f greater than about .05. Figure L-1 is a plot of the percent error in the estimate as a function of $\bar{n}$ for f = .01 and for $\sigma^2/\bar{n}$ = 0.25, 0.50, 1.0, 2.0, 5.0 and 10.0.

To derive the result, let f_n be the probability that one or more spills have exceeded the specified volume, given that exactly n spills have occurred. Then

$$f_{n+1} = f_n + f - ff_n \tag{3}$$

where $f = f_1 = 1 - F(x)$. The product term ff_n is small, suggesting that f_n may be approximated by nf. Let

$$f_n = nf - e_n, \tag{4}$$

where e_n is the error in the approximation.

The probability f_n applies to exactly n spills. Considering all possible values for n gives the desired probability, P(=P(x)):

$$P = \sum_{n=0}^{\infty} f_n p(n) \tag{5}$$

where p(n) is the probability of exactly n spills in the interval. From (4),

$$\begin{aligned} P &= \sum_{n=0}^{\infty} nf\, p(n) - E \\ &= \bar{n}f - E \\ &= \bar{n}\left(1 - F(x)\right) - E \end{aligned} \tag{6}$$

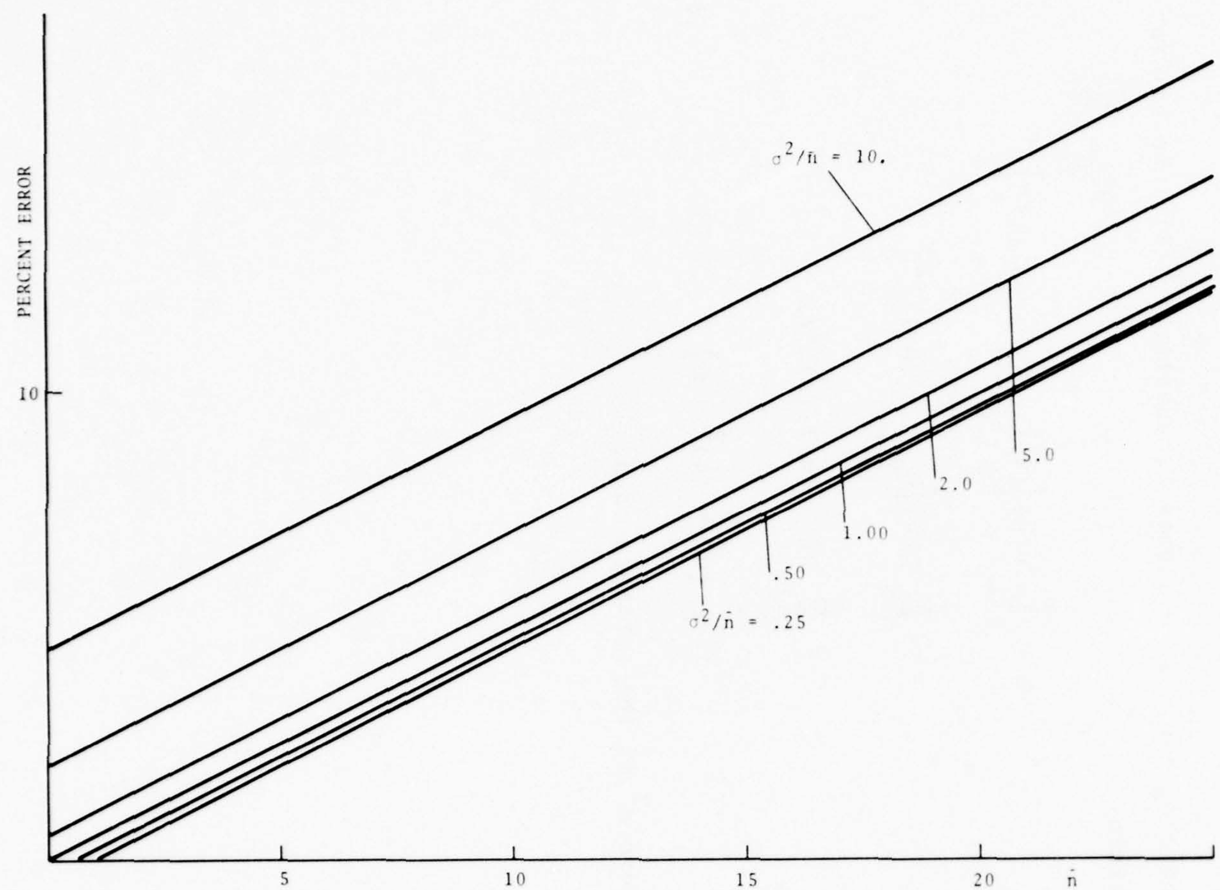

FIGURE L-1 PERCENT ERROR IN ESTIMATE OF P(x) AS A FUNCTION OF EXPECTED NUMBER $\bar{n}$ OF SPILLS

as stated initially, where the error in P is E:

$$E = \sum_{n=0}^{\infty} e_n \, p(n) \tag{7}$$

where $e_o = 0$. To evaluate E, substitute (4) into (3) to obtain

$$E = \sum_{n=1}^{\infty} p(n) \left[(1-f) e_{n-1} + (n-1) f^2 \right]$$

$$\leq \sum_{n=1}^{\infty} p(n) \left[e_{n-1} + (n-1) f^2 \right]$$

$$\leq \sum_{n=1}^{\infty} p(n) \; (n-1)(n) f^2/2.$$

$$\leq \frac{f^2}{2} \left(\sigma^2 + (\bar{n})^2 - \bar{n} \right) \tag{8}$$

where σ^2 is the variance of n.

2. PROBABILITY OF LARGE SPILLS - POISSON DISTRIBUTION

If one is willing to assume that the spill number is Poisson distributed, and independent of spill size, then an exact answer to the large spill question is easily obtained. If n spills occur in an interval T then they constitute n Bernoulli trials, each with probability f(x) that it will exceed the level x. The probability that exactly k of these n spills will exceed x gallons is therefore Binomially distributed:

$$B(k/n) = \binom{n}{k}\left[f(x)\right]^k\left[1 - f(x)\right]^{n-k} . \qquad (9)$$

When all possible values of n are considered, one has the probability $P_k(x)$ that exactly k spills will exceed the value x:

$$P_k(x) = \sum_{n=k}^{\infty} B(k/n)\ p(n), \qquad (10)$$

where p(n) is the probability of n spills in the interval T. If, now, one assumes that p(n) is a Poisson distribution, i.e.,

$$p(n) = (\lambda T)^n\ e^{-\lambda T}/n! \qquad (11)$$

he obtains the following from (10) and (9) for $n \geq k$:

$$P_k(x) = \frac{\left[f(x)\right]^k\ e^{-\lambda T}(\lambda T)^k}{k!} \sum_{n=k}^{\infty} \frac{\left[\lambda T\left(1 - f(x)\right)\right]^{n-k}}{(n-k)!}$$

$$= \left[\lambda T f(x)\right]^k\ e^{-\lambda T f(x)}/k! \qquad (12)$$

which indicates that the number of spills larger than x gallons is <u>also</u> Poisson distributed, with intensity parameter $\lambda f(x)$, if the total number of spills is Poisson distributed with parameter λ.

From (12) it follows that the probability of one or more spills of size greater than x is P:

$$\begin{aligned} P &= 1 - P_o(x) \\ &= 1 - e^{-\lambda T f(x)} \\ &= \lambda T\ f(x) - \left(\lambda T\ f(x)\right)^2/2! + \cdots . \end{aligned} \qquad (13)$$

When only the first term is taken, one obtains the approximation (1) previously arrived at:

$$P \cong \bar{n} f(x), \qquad (14)$$

where $\bar{n} = \lambda T$ and $f(x) = (1 - F(x))$. In this case the error E is bounded by the first term discarded in the alternating series:

$$E \leq f^2\ \bar{n}^2/2 . \qquad (15)$$

3. PROBABILITY OF SIMULTANEOUS LARGE SPILLS

In this section we derive the probability that one or more spills greater than y gallons will occur while recovery efforts are still in progress for a spill of size x gallons. This result has implications for the selection of storage levels for pollution response equipment.

First it is necessary to estimate the probability of a spill of size between x gallons and x + Δx gallons. This is h(x)

$$h(x) = F(x+\Delta x) - F(x). \tag{16}$$

If n spills occur the probability that exactly k of them will be between x and x + Δx is

$$B(k/n) = \binom{n}{k}\left[h(x)\right]^k\left[1 - h(x)\right]^{n-k}, \tag{17}$$

just as in (9) above. By an argument similar to that employed for (9) - (12) above, one may determine the probability that exactly k spills are in the range x to x + Δx, with a result analogous to (12):

$$P_k(x) = \left[\lambda T\ h(x)\right]^k e^{-\lambda T h(x)}/k!. \tag{18}$$

As in (11) it has been assumed that spill number is Poisson distributed. In the present case, however, it is more convenient to interpret T and λ as time and spills per unit time, rather than as throughput and spills per unit throughput.

Next it is necessary to assume that some relation $\delta(x)$ exists between spill duration δ and spill size x.* The duration of a spill is taken as the time during which USCG pollution response equipment is required to cope with it. In general, the larger x, the larger will be $\delta(x)$. The probability of a spill of more than y gallons occurring within $\delta(x)$ times units from the start of one of size x gallons is obtained from (12) by replacing T by $\delta(x)$ and f(x) by f(y), to get q:

$$q = 1 - e^{-\lambda\delta(x)f(y)} \left(\equiv q(x,y)\right) \tag{19}$$

$$\cong \lambda\delta(x)f(y), \text{ if } \lambda\delta(x)f(y) << 1.$$

If there are exactly k spills of size x, with probability given by (18), then the probability that j of them ($j \leq k$) will be simultaneous with spills larger than y is Q(j/k):

$$Q(j/k) = \binom{k}{j} q^j \ (1-q)^{k-j} \ , \tag{20}$$

and the net probability of j spills of size greater than y, simultaneous with spills of size x, is

$$S(j,y,x) = \sum_{k=0}^{\infty} Q(j/k)\ P_k(x) \ , \ j \geq k \ , \tag{21}$$

---

*By a spill of size x is meant a spill in the size range x to x + Δx.

Substituting (18) and (20) into (21) gives, after a calculation similar to that of (12),

$$S(j,y,x) = \left[\lambda T\omega(x,y)\right]^j e^{-\lambda T\omega(x,y)}/j! \qquad (22)$$

where

$$\omega(x,y) = h(x) \left(1 - e^{-\lambda\delta(x)f(y)}\right) \qquad (23)$$

If the probability is small of a second spill of size y or greater occurring in the interval $\delta(x)$, then the approximation in (19) may be used, giving

$$\omega(x,y) \cong \lambda\ h(x)\ \delta(x)\ f(y) \qquad (24)$$

1. It should be noted that j here is not the number of spills occurring simultaneously, but the number of times that simultaneous spills occur, i.e., the number of times in the period T that one or more spills of size greater than y occur during a spill of size x.

2. It should also be noted that the calculation is not restricted to large spills if the exact form (23) is used instead of the approximation (24). Moreover, (24) is a good approximation as long as $\lambda\ \delta(x)f(y)$ is small, which can occur if (a) the spill rate λ is small, or (b) the duration $\delta(x)$ of the first spill is small, or (c) the second spill size, y, is so large that the probability f(y) of its occurrence is small, or if (d) some combination of (a), (b) and (c) occurs.

The function S(j, y, x) is plotted in Figure L-2, for λ = 20 spills/year, T=1 year, $\Delta x = \infty$, $x = y \geq 50{,}000$ gallons, F(x) from Figure 3-5, and $\delta(x) = 5$ days.

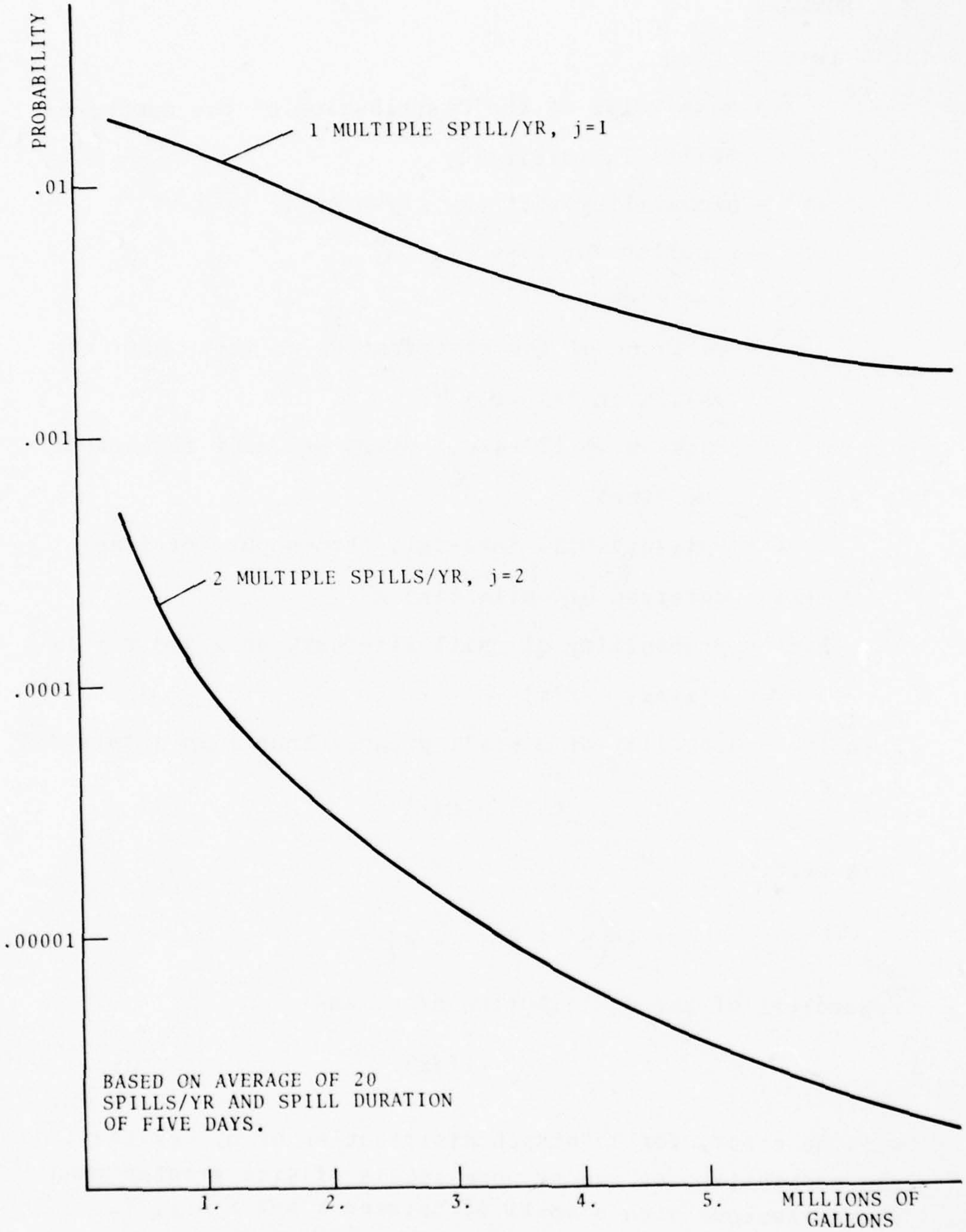

FIGURE L-2 PROBABILITY OF MULTIPLE SPILLS

4. SUMMARY

Let

$\bar{n}$ = mean value of the distribution of the number of spills in interval T

$F(x)$ = probability that any given spill will be x gallons or less

$f(x) = 1 - F(x)$

σ^2 = variance of the distribution of the number of spills in interval T

λ = Poisson spill rate, spills per unit throughput (or time)

T = Poisson spill interval, throughput (or time)

$\delta(x)$ = duration of spill size x

$h(x)$ = probability of spill size between x and $x + \Delta x$

$= F(x+\Delta x) - F(x)$

Then the probability of a spill greater than x in interval T is

$$\bar{n}\ (1 - F(x))$$

with error

$$f^2\left(\sigma^2 + (\bar{n})^2 - \bar{n}\right)/2$$

regardless of the distribution of n, and

$$1 - e^{-\lambda T f(x)}$$

with no error, for a Poisson distribution of n. Further, the probability of one or more spills of size greater than y simultaneous with a spill of between x and $x + \Delta x$ is

$$\left[\lambda T\omega(x,y)\right]^{j} e^{-\lambda T\omega(x,y)}/j!$$

where

$$\omega(x,y) = h(x)\left(1 - e^{-\lambda\delta(x)f(y)}\right)$$

and where j is the number of times in T that simultaneous spills occur.

APPENDIX M:

NON-COAST GUARD EQUIPMENT CAPABILITIES

Appendix M contains a discussion and presentation of geographical locations and performance capabilities of the following selective pieces of pollution response equipment:

1. Booms
2. Skimmers
3. Pumps
4. Storage Containers

The capabilities presented herein are predicated upon a knowledge of the extent of existing equipment inventories and some reasonable assumption s concerning the availability and performance degradation that reflect pseudo-real-world situations. Emphasis is placed upon Non-Coast Guard equipment inventories such as those owned and operated by:

1. U.S. Navy
2. Private Companies
3. Cooperatives
4. States, Cities, and Towns

Emphasis was also placed upon equipment stored at locations close to the shoreline of the states including the Great Lakes. Close means within approximately 100 miles. All other inland locations were deleted from the established inventories.

The bulk of the equipment information was derived from a data base entitled, Spill-Cleanup Inventory, developed by the Coast Guard at headquarters. It, in turn, was compiled from data supplied by the existing strike teams, MSO's and CTOP's. TSC then collapsed this data base further by aggregating all non-federal government owned equipment at or near previously specified port cities. In short, this then becomes the total amount of capability that can be called up and deployed subsequent to a notification at a spill, grounding, etc. The resulting collapsed data base is given on Table M-1.

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

TRANSFER-LIGHTERING SYSTEMS

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL PUMP CAPACITY GPM	TOTAL STORAGE IN GALLONS
PEABODY	MA	4229	7058	3	900	
JOHNSTON	RI	4149	7128	1	100	300
NEW HAVEN	CT	4119	7254	5	1,320	40,000
BALTIMORE	MD	3916	7636	1	500	2,930
WILMINGTON	NC	7755	3415	1	300	
TAMPA	FL	2757	8226	1		2,500
FLOUR BLUFF	TX	2736	9717	1		630
CORPUS CHRISTI	TX	2755	9731	3	45	94,500
MILWAUKEE	WI	4300	8755	1	600	6,000
ST JOSEPH	MI	4206	8628	1	75	300
OREGON	OH	4137	8329	48	3,510	366,000
LONG BEACH	CA	3343	11817	2		
CONCORD	CA	3739	12216	1		
PORTLAND	OR	4534	12243	1	1,000	

TANKSHIPS

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL CAPACITY IN GALLONS
BOSTON	MA	4223	7102	6	59,500
DETROIT	MI	4216	8307	2	1,260,000
SEATTLE	WA	4735	12221	1	3,500

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT (CONTINUED)

PUMPS WITH CAPACITY ≥ 200 GPM

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL PUMP CAPACITY GPM
STOUGHTON	MA	4215	7107	13	5,500
BOSTON	MA	4221	7102	23	11,390
GLOUCESTER	MA	4238	7035	3	1,500
BRIDGEWATER	MA	4139	7014	8	3,150
FALMOUTH	MA	4131	7037	8	2,240
BANGOR	ME	4448	5846	2	400
PORTLAND	ME	4338	7017	8	10,160
GRAY	ME	4342	7012	1	260
SOMERSET	MA	4230	7111	4	960
JOHNSTON	RI	4149	7128	3	1,500
DUBUQUE	IL	4230	9030	6	360
ROCK ISLAND	IL	4130	9030	2	200
SPRING PARK	MN	4500	9310	1	380
EAU CLAIRE	WI	4450	9212	3	1,485
SPOONER	WI	4555	9155	1	385
SPRING PARK	MN	4450	9337	2	380
WOOD RIVER	IL	3854	9006	1	340
HARTFORD	IL	3845	9008	1	300
GRANITE CITY	IL	3842	9010	3	700
RENSSELAER	NY	4239	7344	2	575
WEST HAVEN	CT	4117	7256	1	350
BAYONNE	NJ	4040	7406	12	8,380
NEWARK	NJ	4044	7405	1	300
LONG ISLAND CY	NY	4045	7358	2	400
NEWARK	NJ	4042	7047	1	600
VERPLANK	NY	4115	7458	1	350
EDISON	NJ	4420	7430	10	2,600
CLAYTON	NJ	3940	7509	2	500
BALTIMORE	MD	3914	7636	42	21,555

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

PUMPS WITH CAPACITY $\geq$ 200 GPM (CONTINUED)

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL PUMP CAPACITY GPM
NORFOLK	VA	3650	7617	4	2,200
CHARLESTON	SC	3250	7958	2	3,600
MIAMI	FL	2526	8020	4	1,243
FT LAUDERDALE	FL	2604	8012	1	200
SAVANNAH	GA	3204	8105	7	3,550
BRUNSWICK	GA	3109	8129	1	250
CAGUAS	PR	1826	6606	6	225
CAGUAS	PR	1826	6606	5	2,750
CAGUAS	PR	1826	6606	5	1,500
HOUSTON	TX	2940	9515	15	300
HOUSTON	TX	2944	9508	21	187,250
GULFPORT	MS	3023	8906	1	380
MIDFIELD	AL	3328	8655	1	200
VENICE	LA	2916	8929	1	200
NEW ORLEANS	LA	2936	9043	8	1,600
MORGAN CITY	LA	2941	9113	1	300
HARVEY	LA	3000	9002	167	260,000
HARAHAN	LA	2925	9012	1	1,725
HOUMA	LA	2936	9043	15	3,000
WESTWEGO	LA	3000	9002	1	1,000
PORT ARTHUR	TX	2949	9354	7	9,500
LAKE CHARLES	LA	3010	9319	2	440
BEAUMONT	TX	3002	9402	2	1,200
SULPHUR	LA	3014	9323	13	2,900
PORT NECHES	TX	2959	9358	2	15,000
NEDERLAND	TX	2957	9400	13	2,660
CICERO	IL	4150	8746	8	4,710
CHICAGO	IL	4143	8733	13	27,310
LOCKPORT	IL	4140	8803	1	1,300
FINLAY	IL	4125	8850	1	700

TABLE M-1 NON FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

PUMPS WITH CAPACITY $\geq$ 200 GPM (CONTINUED)

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL PUMP CAPACITY GPM
LEMONT	IL	4140	8800	3	880
FINLAY	IL	4125	8850	1	900
BLUE ISLAND	IL	4140	8741	1	300
LEMONT	IL	4140	8801	3	900
BRIDGEVIEW	IL	4145	8748	1	1,200
FINLAY	IL	4125	8850	1	700
TRENTON	MI	4208	83135	31	25,055
BAY CITY	MI	4337	83505	1	1,500
ECORSE	MI	4215	8309	2	1,280
MOUNT CLEMENS	MI	4235	82472	8	2,860
DETROIT	MI	4217	83070	4	12,800
KAWKAWLIN	MI	4340	8353	1	1,500
ROSEVILLE	MI	4230	82576	1	360
INKSTER	MI	4218	8320	7	2,940
WAYNE	MI	4217	8324	2	1,000
FERNDALE	MI	4228	8306	3	1,020
BAYFIELD	WI	4750	9105	1	250
HOUGHTON	MI	4707	8835	3	2,400
SUPERIOR	WI	4642	9202	10	3,400
HOLLAND	MI	4243	8607	1	1,000
FRUITPORT	MI	4307	8610	3	965
PENTWATER	MI	4345	8625	6	2,615
MUSKEGON	MI	4313	8620	40	17,395
FRUITPORT	MI	4307	8610	3	600
RAPID RIVER	MI	4445	8557	9	3,400
PLAINWELL	MI	4227	8538	3	3,600
FRANKFORT	MI	4440	8615	3	900
ELBERTA	MI	4438	8615	1	200
ST JOSEPH	MI	4206	8628	5	1,500
OXNARD	CA	3410	11911	4	950

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

PUMPS WITH CAPACITY $\geq$ GPM (CONTINUED)

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL PUMP CAPACITY GPM
VENTURA	CA	3424	11930	1	500
LONG BEACH	CA	3347	11813	8	2,360
NATIONAL CITY	CA	3240	11706	20	5,000
MONTEREY	CA	3637	12154	6	1,350
SAN LUIS OBIS	CA	3509	12046	1	600
MORRO BAY	CA	3522	12052	2	500
CROCKETT	CA	3803	12213	5	1,200
PITTSBURG	CA	3801	12151	2	4,000
BENICIA	CA	3802	12208	3	1,500
OAKLAND	CA	3746	12213	3	600
ANTIOCH	CA	3800	12146	4	6,000
MARTINEX	CA	3808	12208	13	7,500
SO SAN FRAN	CA	3738	12223	28	8,600
EMERYVILLE	CA	3750	12218	5	1,650
PORTLAND	OR	4534	12243	6	7,430
SEATTLE	WA	4740	1220	14	10,450
FEDERAL WAY	WA	4720	12222	2	600

OPEN-WATER SKIMMERS

CITY	STATE	EQUIPMENT LOC LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL RECOVERY CAPACITY IN GPM
MOSS LANDING	CA	3648	12147	1	10
CONCORD	CA	3739	12216	1	
RODEO	CA	3803	12215	1	
MARTINEZ	CA			1	40
SAN FRANCISCO	CA	3747	12223	4	206
EMERYVILLE	CA	3750	12218	2	200
PORTLAND	OR	4534	12243	10	1,621

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

OPEN-WATER SKIMMERS (CONTINUED)

CITY	STATE	EQUIPMENT LOC LAT	EQUIPMENT LOC LONG	TOTAL NUMBER OF UNITS	TOTAL RECOVERY CAPACITY IN GPM
ANACORTES	WA	4831	12236	3	290
FERNDALE	WA	4852	12245	1	265
BELLINGHAM	WA	4846	12230	1	
HONOLULU	HI	1944	15503	1	30
PEABODY	MA	4229	7058	1	750
PORLAND	ME	4342	7012	1	25
DAVISVILLE	RI	4136	7125	4	2,000
FINDLAY	OH	4102	8340	4	
NEW HAVEN	CT	4119	7254	1	200
BROOKLYN	NY	4040	7401	1	
ELIZABETH	NH	4039	7411	2	
MIAMI	FL	2548	8013	5	208
FT LAUDERDALE	FL	2605	8007	2	205
BRUNSWICK	GA	3109	8129	1	40
SAVANNAH	GA	3205	8106	1	600
YABACOA	PR	1803	6550	1	20
SAN JUAN	PR	1828	6607	5	60
SAN JUAN	PR	1826	6606	1	40
FLOUR BLUFF	TX	2736	9717	1	500
BAYTOWN	TX	2943	9501	2	70
VENICE	LA	2916	8929	1	
INTERCOASTAL	LA	2947	9209	1	
NEW ORLEANS	LA	2936	9043	5	
BELLE CHASE	LA	3000	9002	2	588
SULPHUR	LA	3014	9323	2	400
WADDINGTON	NY	4452	7512	2	1,000
WAYNE	MI	4217	8324	1	300
MOUNT CLEMENS	MI	4235	82472	5	2,100
BAY CITY	MI	4337	83505	1	100
VENTURA	CA	3424	11954	6	650
LOS ANGELES	CA	3423	12003	1	15
SANTA BARBARA	CA	3424	11930	16	5,643

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

BARGES (CONTINUED)

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL CAPACITY IN GALS
STOUGHTON	MA	4215	7107	2	17,500
EAST BOSTON	MA	4222	7102	7	53,905
FALMOUTH	MA	4131	7037	4	
MENEMSHA	MA	4123	7050	1	15,000
CHELSEA	MA	4127	7036	3	210,000
FALMOUTH	MA	4131	7037	5	
CHARLESTOWN	MA	4223	7103	20	600,000
SO PORTLAND	ME	4342	7012	1	
PORTLAND	ME	4345	7012	13	804,000
KITTERY	ME	4305	7045	1	75,000
LAWRENCEBURG	IN	3901	8450	1	
LOUISVILLE	KY	3818	8540	1	5,000
MEMPHIS	TN	3505	9006	1	
ST PAUL	MN	4450	9310	1	600
CAPE GIRARDNA	MO	3718	8930	1	879,900
MILFORD	CT	4113	7302	2	
PHILADELPHIA	PA	3953	7511	10	33,967,240
CAMDEN	NJ	3958	7505	2	
NORFOLK	VA	3650	7617	1	60,000
CHARLESTON	SC	3251	7957	6	116,510
JACKSONVILLE	FL	3019	8139	2	829,500
FT LAUDERDALE	FL	2605	8007	2	1,000
SAVANNAH	GA	3205	8106	4	1,078,000
PONCE	PR	1758	6637	3	1,533,000
GUAYAMA	PR	1756	6608	1	1,176,000
TAMPA	FL	2757	8226	5	
CORPUS CHRISTI	TX	2749	9724	3	504
HOUSTON	TX	2943	9513	2	55
MOBILE	AL	3042	8802	1	
ABBEVILLE	LA	2947	9209	30	

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

BARGES (CONTINUED)

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL CAPACITY IN GALS
BELLE CHASE	LA	3000	9002	6	
NEW ORLEANS	LA	2916	8957	2	4,200
INTERCOASTAL	LA	2947	9209	2	4,200
MORGAN CITY	LA	2941	9113	3	
HOUMA	LA	2936	9043	7	
BERWICK	LA	2941	9113	12	
VENICE	LA	2916	8929	2	192,570
PORT ARTHUR	TX	2952	9356	4	22,000
CHICAGO	IL	4143	8733	3	
CICERO	IL	4150	8746	1	
LEMONT	IL	4140	8801	1	1,000
CLEVELAND	OH	4131	81415	3	6,000,000
DETROIT	MI	4217	83070	2	6,400
MOUNT CLEMENS	MI	4235	82472	1	4,000
SUPERIOR	WI	4649	9202	5	
DULUTH	MN	4647	9205	2	1,400
SUPERIOR	WI	4649	9202	5	78,000
MUSKEGON	MI	4312	8620	29	15,000
FRANKFORT	MI	4440	8615	2	
RAPID RIVER	MI	4445	8537	3	
FERRYSBURG	MI	4305	8620	8	
ST JOSEPH	MI	4205	8630	4	
FRUITPORT	MI	4307	8610	1	15,000
FERRYSBURG	MI	4305	8610	3	
OREGON	OH	4140	8328		
SANTA BARBARA	CA	3408	11912	1	329,280
NATIONAL CITY	CA	3240	11706	3	680,400
MOSS LANDING	CA	3648	12147	1	748
ALAMEDA	CA	3747	12217	2	1,320
SAN FRANCISCO	CA	3747	12223	2	175,968

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

BARGES (CONTINUED)

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL CAPACITY IN GALS
RICHMOND	CA	3754	12222	12	
EMERYVILLE	CA	3750	12218	1	
BELLINGHAM	WA	4846	12230	1	3,200
SEATTLE	WA	4740	12220	1	

RUBBER BLADDERS

CITY	STATE	LAT	LONG	TOTAL NUMBER OF UNITS	TOTAL CAPACITY IN GALS
MIAMI	FL	2548	8013	3	1,500
BRUNSWICK	GA	3112	8133	2	20,000
BELLE CHASE	LA	3000	9002	2	10,000
FINLAY	IL	4150	8850	1	12,000
MORRIS	IL	4123	8823	1	1,000
ECORSE	MI	4215	8309	1	500
LOS ANGELES	CA	3523	12003	1	1,200
SANTA BARBARA	CA	3424	11930	8	17,200
EUREKA	CA	4046	12412	1	2,500
RICHMOND	CA	3754	12222	2	1,250
CONCORD	CA	3739	12216	2	
PORTLAND	OR	4534	12243	5	9,000

OFFSHORE BOOMS (WAVE HEIGHTS > 3 FT.)

CITY	STATE	LAT	LONG	TOTAL LENGTH FEET	TOTAL NUMBER OF UNITS
GLOUCESTER	MA	4238	7035	300	6
PEABODY	MA	4229	7058	612	1
BEVERLY	MA	4233	7053	600	12

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

OFFSHORE BOOMS (WAVE HEIGHTS > 3 FT.) (CONTINUED)

CITY	STATE	LAT	LONG	TOTAL LENGTH FEET	TOTAL NUMBER OF UNITS
LONGISLAND	ME	4342	7004	750	1
DAVISVILLE	RI	4136	7125	1,000	10
TIVERTON	RI	4138	7114	2,000	20
BAYONNE	NJ	4039	7407	5,000	100
PERTH AMBOY	NJ	4031	7415	1,000	40
ELIZABETH	NJ	4039	7411	2,500	50
JACKSONVILLE	FL			1,730	1
FT LAUDERDALE	FL	2605	8007	10,500	3
SAVANNAH	GA	3204	8105	1,500	30
BRUNSWICK	GA	3112	8132	750	18
ST PERTERSBURG	FL	2751	8236	800	8
BOCA GRAND	FL	2738	8233	1,410	44
CORPUS CHRISTI	TX	2749	9724	540	1
HOUSTON	TX	2940	9515	6,000	190
MOBILE	AL	3045	8803	2,000	40
PANAMA CITY	LA	3009	8536	1,640	82
BATON ROUGE	LA	3030	9110	102	48
NEW ORLEANS	LA	3000	9002	1,500	30
CHICAGO	IL	4141	8733	930	9
RIVER ROUGE	MI	4216	83080	350	7
MILWAUKEE	WI	4300	8755	200	4
TOLEDO	OH	4139	8332	400	4
SANTA BARBARA	CA	3424	11941	3,600	12
VENTURA	CA	3420	11938	2,800	11
LOS ANGELES	CA	3423	12003	1,400	2
MORRO BAY	CA	3522	12052	30,000	1
SAN LUIS OBISBO	CA	3510	12044	1,300	26
PITTSBURG	CA	3802	12253	1,800	2
HERCULES	CA	3801	12216	2,200	1
SEATTLE	WA	4735	12221	9,750	71
BELLINGHAM	WA	4845	12230	7,000	60

TABLE M-1 NON-FEDERAL GOVERNMENT POLLUTION RESPONSE EQUIPMENT

OFFSHORE BOOMS (WAVE HEIGHTS > 3 FT.) (CONTINUED)

CITY	STATE	LAT	LONG	TOTAL LENGTH FEET	TOTAL NUMBER OF UNITS
RENTON	WA	4729	12212	1,200	2
FERNDALE	WA	4852	12245	4,640	62
MUKILTEO	WA	4756	12217	1,500	3
TACOMA	WA	4716	12225	300	3
MANCHESTER	WA	4733	12234	2,100	42
PORT ANGELS	WA	4846	12326	1,000	10
OAK HARBOR	WA	4810	12236	600	1

The capabilities of U.S. Navy equipment - predominantly barges, skimmers, and booms were derived from information supplied by:

1. Navfac
2. Navsea

The locations and equipment levels shown on Table 9C-2 are, however, tentative at the present time. Since there is an abundance of harbor booms, the number of feet of Navy booms was not included. The barges and skimmers are attractive candidates for recovery operations.

The following three pieces of equipment were added to the total available capability from the Navy inventory:

1. JBF 3001 Skimmer
2. Mark Class V Skimmer
3. Ship's Waste Offload Barge (SWOB)

These are essentially harbor and coastal equipment, however, under reasonably good environmental conditions they can be employed in open waters. A small skimmer, if it can survive, has better wave-following characteristics than a large heavier one with correspondingly higher moments of inertia, etc., but its ability to survive is doubtful unless accompanied or protected by a larger vessel.

The Dip 3001 skimmer is a self-contained skimming system. It is designed to harvest oil in the open harbor with waves up to two feet in height. It can also operate effectively in between piers or in a stationary mode at the apex of a boom catenary configuration. This unit is approximately 25 feet long and 10 feet wide. Articulating sweeps extend the skimming width to 15 feet. It is diesel powered with two screws for propulsion. All pumping, propulsion, and belt functions are hydraulically operated. One thousand gallons of storage capacity is provided on board for collected oil.

TABLE M-2

U.S. NAVY EQUIPMENT

NUMBER	DESCRIPTION	LOCATION
1	Skimmer*	Earle, NJ
1	Skimmer	Portsmouth, NH
2	SWOB**	" "
1	Skimmer	Newport, RI
1	Skimmer	New London, CT
1	SWOB	" "
1	Skimmer	Philadelphia, PA
2	SWOB	" "
8	SWOB	Norfolk, VA
2	Skimmer	" "
1	SWOB	Portsmouth, VA
1	Skimmer	" "
3	SWOB	Little Creek, VA
1	Skimmer	" "
4	SWOB	Charleston, SC
2	Skimmer	" "
1	Skimmer	Pensacola, FL
1	Skimmer	Mayport, FL
1	Skimmer	Pascagoula, FL
3	Skimmer	San Diego, CA
7	SWOB	" "
3	SWOB	Long Beach, CA
1	Skimmer	" "
1	Skimmer	Panama City, FL
1	Skimmer	Almeda, CA
1	Skimmer	Vallejo, CA
1	SWOB	" "
1	Skimmer	Richmond, CA
3	SWOB	" "
1	Skimmer	Keyport, WA
1	Skimmer	Bancor, WA

TABLE M-2 (CONT'D)

U.S. NAVY EQUIPMENT

NUMBER	DESCRIPTION	LOCATION
1	Skimmer	Manchester, WA
5	SWOB	Bremerton, WA
1	Skimmer	" "
4	Skimmer (Mod)*	Yorktown, VA
4	Skimmer	Yorktown, VA
4	Skimmer	Stockton, CA
4	Skimmer (Mod)	Stockton, CA

*JBF-3001 Skimmer, up to 100 gal./min.

**Ship's Waste Offload Barge (SWOB), 75,000 gal.

***Marco Class V Skimmer 300 gpm

(Mod) Modified Class V Skimmer

The Marco Class V Skimmer is a similar device having about the same applications. The Navy plans to modify some of their Class V Skimmers. They will be subdivided into three sections requiring reassembly at the scene of the spill. The sections will be bolted together (4 bolts) and will require no plumbing, electrical connections, etc. This approach circumvents the need for special permits for over-the-road transportation. These permits are not obtainable during the evening or weekends. Also, large expansive cargo carrying aircraft are not needed since two C-130's can carry the three Marco Skimmer sections.

The SWOB is a large floating tank with offloading pumps. The purpose of the SWOB is to collect oily waste. It is essentially a non-self-propelled floating tank 106 feet long by 26 feet wide having a storage capacity of 75,000 gallons. The onboard diesel prime mover supplies power to two electrically driven 160 gpm offloading pumps. The pumps are for only offloading the SWOB. The SWOB can accept waste flow rates up to 400 gpm. Four 50 foot lengths of 2-1/2 inch hose together with hose handling equipment are provided with each barge. A tug or comparable vessel is required for movement of the SWOB. The SWOB is a possible candidate storage of pollutants subsequent to skimming or lightering operations.

TSC limited the comprehensive U.S.C.G. Spill Cleanup Inventory to the following:

1. Heavy duty offshore booms
2. Open-water skimmers
3. Pumps, transfer/lightering systems
4. Barges, tankships, and rubber bladders

The derived capabilities are considered a function of the following characteristics:

1. Total feet of available offshore booms for:
   A. Sea state (0-3 ft.)
   B. Sea state (over 3 ft.)
2. Total gallons capacity of available:
   A. Barges
   B. Tankships
   C. Bladders
3. Maximum recovery rate (gpm) of skimmers*
4. Storage (gal.) and pumping rates (gpm) of:
   A. Pumps*
   B. Transfer/lightering systems

All hand-held skimmers and vacuum types were deleted.

The amount of pollutant or oil to be recovered or offloaded respectively, the location, and some primitive form of scenario (time intervals over which specified recovery operations are performed) must be established to facilitate the estimate of required equipment capability levels. This together with the estimate of the actual levels indicated in the inventories will point out areas where there are excessive amounts of capability or deficiencies. The equipment capability levels contained herein are based upon a subjective judgement of the availability of equipment and some factor for degrading performance to account for the influence of average environmental conditions and product types.

Availability is the fraction of the response equipment that is operational and/or not diverted to the performance of other services from which revenue is derived.

Since the maximum performance of skimmers and pumps is usually specified, it is assumed that the above-mentioned inventories contain maximum values. Tables M-3 and 4 are tabulations of the factors that were employed to yield more realistic values. The following is a description of the primitive scenarios employed.

*limited to units that exceed or are equal to 200 gpm.

TABLE M-3

NON-COAST GUARD

HARBOR EQUIPMENT CAPABILITY

PERFORMANCE CHARACTERISTICS

EQUIPMENT TYPE	AVAILABILITY	% OPERATING HOURS/DAY	AVERAGE CAPABILITY % OF MAX.	% of OIL RECOVERED	% * ENCOUNTERED	PERIOD OF OPERATION HRS.
Booms	0.8	100	-	-	-	
Skimmers	0.8	67	80	55	35	88
Pumps	.95	92	60	-	-	88
Storage for Skimming	0.8	--	--	-	-	78
Storage for Offloading	0.8	--	--	-	-	78

*Percent of operating time pollutant is actually pumped or skimmed.

TABLE M-4

NON-COAST GUARD

OPEN-WATER EQUIPMENT CAPABILITY

PERFORMANCE CHARACTERISTICS

EQUIPMENT TYPE	AVAILABILITY	% OPERATING HOURS/DAY	AVERAGE CAPABILITY % OF MAX	% OF OIL RECOVERED	% * ENCOUNTERED	PERIOD OF OPERATION HRS
Booms	-	-	-	-	-	-
Skimmers	1.0	42	100	60	35	62
Pumps	.95	75	60	-	-	110
Storage for Skimming	0.8	-	-	-	-	42
Storage for Offloading	0.8	-	-	-	-	90

Pumping operation:

A. Harbors

Pumping starts 8 hours after notification.

Pumping ends 4 days after notification.

B. Open Waters

Pumping starts on 10th hour

Pumping ends on 5th day

Containment operation

Capability not time dependent

Skimming operation:

A. Harbors

Skimming starts on 8th hour

Skimming ends on 4th day

B. Open waters

Skimming starts on 10th hour

Skimming ends on 3rd day.

Storage associated with offloading operations:

A. Harbor

Dracones put into service on 8th hour

Dracones removed on 18th hour

Barges put into service on 18th hour

Barges removed on the 4th day

B. Open Water

Dracones put into service on 10th hour

Dracones removed on 30th hour

Barges put into service on 30th hour

Barges removed on 5th day

Storage associated with skimming operations:

A. Harbor

Same as storage under offloading operations

B. Open Water

Dracones put into service on 10th hour

Dracones removed on 30th hour

Barges put into service on 30th hour

Barges removed on 3rd day.

In order to calculate the spill response capabilities of equipment available to each site of Configuration 5 from organizations other than the Coast Guard, we define the following quantities at each of n locations close to the site in question:

S_n = maximum skimming capability (gals/hr.)

P_n = maximum pumping capability (gals/hr.)

Q_n = floating storage capacity (gals.)

C_n = boom containment capacity (gals.)

$\sim (2/3\ L_n) \times 10^3$, where

L_n = boom length (ft.)

The relation between containment capacity and boom length was arrived at by selecting a nominal harbor spill size and boom effectiveness. Thus, on the assumption that 3,000 feet of boom can contain 2,000,000 gallons of oil, L_n feet of boom have been assigned a nominal capacity equal to the integral part of $L_n/3{,}000$ times 2,000,000 gallons.* The total response capability available to each site is proportional to the sum for the n locations nearest to each site. Complete formulas for harbor and open-water equipment are given in Tables M-5 and M-6. Numerical results for each site of Configuration 5 are given in Tables M-7 and M-8.

*Two million gallons of oil is approximately half the cargo of a tanker of 10,000 gross tons.

TABLE M-5

NON-COAST GUARD HARBOR EQUIPMENT

FORMULAS FOR TOTAL CAPABILITY AT EACH SITE

EQUIPMENT TYPE	TOTAL CAPABILITY[1] (SCENARIO PP. M-20)
Skimmers	$S = 7.26 \sum_n S_n$ (gallons)
Pumps	$P = 46.1 \sum_n P_n$ (gallons)
Floating Storage	$Q = 0.80 \sum_n Q_n$ (gallons)
Boom Containment	$C = 0.80 \sum_n C_n = (0.53 \sum_n L_n) \times 10^3$ (gallons)

1. Numerical factors are obtained by multiplying the factors on the corresponding line of Table M-3.

TABLE M-6

NON-COAST GUARD OPEN WATER EQUIPMENT

FORMULAS FOR TOTAL CAPABILITY AT EACH SITE

EQUIPMENT TYPE	TOTAL CAPABILITY[1] (SCENARIO PP. M-20)
Skimmers	$S = 5.47 \sum_{n} S_n$ (gallons)
Pumps	$P = 47.0 \sum_{n} P_n$ (gallons)
Floating Storage	$Q = 0.80 \sum_{n} Q_n$ (gallons)
Boom Containment	None

1. Numerical factors are obtained by multiplying the factors on the corresponding lines of Table M-4.

TABLE M-7
NON-COAST GUARD
HARBOR EQUIPMENT CAPABILITY*
(KILOGALLONS)

SITE	BOOMS	PUMPS	SKIMMERS	STORAGE
Philadelphia, PA	25,588	67,335	43.4	27,296
New Orleans, LA	11,598	735,968	255	15
New York, N.Y.	12,767	38,651	43.4	92
San Francisco, CA	53,514	103,950	1,170	385
Galveston, TX	178	7,150	0	0.044
Los Angeles, CA	7,733	13,502	347	1,422
Pascagoula, MS	11,598	2,145	130	153
Sabine, TX	11,159	79,860	173	17.6
Port Aransas, TX	11,598	0	217	1,587
Boston, MA	4,111	102,052	1,280	621
Portsmouth, VA	11,598	15,950	1,302	621
Seattle, WA	15,491	50,820	434	1,545
Clearwater, FL	5,537	14,418	304	6,213
Chicago, IL	6,451	350,460	0	

*Adjusted

TABLE M-8

NON-COAST GUARD

OPEN-WATER EQUIPMENT CAPABILITY*

(KILOGALLONS)

SITE	BOOMS	PUMPS	SKIMMERS	STORAGE
Philadelphia, PA		69,048	32.5	27,296
New Orleans, LA		754,702	191	6.7
New York, NY		39,635	32.5	92
San Francisco, CA		106,596	877	382
Galveston, TX		7,332	0	0.044
Los Angeles, CA		13,846	260	1,407
Pascagoula, MS		6,048	97.5	154
Sabine, TX		81,892	130	17.6
Port Aransas, TX		0	162.5	0.88
Boston, MA		104,650	959	1,587
Portsmouth, VA		16,356	975	621
Seattle, WA		52,113	325	305
Clearwater, FL		14,785	227	1,529
Chicago, IL		359,380	0	6,201

*Adjusted

APPENDIX N:

A BRIEF REVIEW OF THE BEHAVIOR OF SURFACE OIL SLICKS

When petroleum or petroleum products are spilled on the surface of the sea a complex set of physical changes takes place that are determined by the composition of the oil, the state of the sea, and the prevailing atmospheric conditions. All these factors combine to influence two major processes:

1) Oil movement
2) Oil weathering

The movement of the oil may be either on the surface of the water by spreading and by transport through the action of wind and current, or it may be down into the water column by mixing and subvection due to waves. Weathering is used here to designate the complex of physical, chemical and biological processes that affect the composition of a surface oil slick exposed to a marine environment. Of these the most prominent is the evaporation of the lighter fractions of the oil leaving a residue which interacts with the sea water to form heavy viscous "pancakes" and "tar balls" some of which sink beneath the surface and some of which float. All of these processes are strongly influenced by the amount of oil spilled and its physical and chemical properties.

A variety of empirical and analytical studies have been made of the movement and transformation of oil on the surface of the sea. Many of these have been reviewed and evaluated in Ref. N-1, which is the basic source of material for this discussion.

1.1 OIL MOVEMENT

1.1.1 Wind Induced

The wind at the ocean's surface affects the movement of oil through the generation of surface waves and through the shear stress induced on the slick surface. Neither of these mechanisms is well

understood. No analysis of wave-induced transport has yet been made (1977) that has yielded realistic results, nor is it known how the effects of wind and waves influence each other. Wind induced motions are usually considered in isolation through a so-called "wind factor" which has been empirically approximated as 3% of the wind speed in the direction of the wind vector. This approach, in itself only a very rough approximation, leaves aside the equally large effects of waves and the detailed spatial and temporal fluctuations of the wind so that the confidence level of analytical results is rather low.

1.1.2 Current Induced

Calculation of the effects of surface and subsurface ocean currents is in an even less satisfactory state than those of the wind since there are many components of such currents, none of which has been adequately modeled. These include: wind-induced currents, large scale ocean currents, currents induced by bottom effects and tidal currents. There are no simple factors that can account for all of these and none can be ignored without large error. Attempts at modeling oil slick movements using available statistics of ocean winds and currents have produced random walk patterns that sometimes trend in the right direction but are grossly inaccurate with respect to the place and time of arrival at any particular point. Furthermore, as the slick approaches shallow waters, the bottom effect is strong, but as yet indeterminate.

1.1.3 Subsurface Transport

Subsurface transport seems to be largely the result of dissolution and dispersion due to wave action. No more than a few percent of the slick is removed by these mechanisms, which are much less important than evaporation in reducing the volume of the oil slick. There is very little data on either of these processes.

1.1.4 Spreading

Oil slick spreading is defined as the movement of oil on the surface of the water relative to the center of mass of the slick. This movement is governed by gravitational, viscous and surface tension forces and by the processes that change the mass of oil in the slick. All of these forces are different for different components of the oil so that some spread much faster than others, with the result that the oil tends to fractionate into viscous clumps (pancakes) within thinner patches of more rapidly spreading components. These pancakes may cover only 10 percent or less of the area encompassed by the oil (Reference N-1, pp. 4-32).

An additional complication is that analytical spreading models assume radial spreading whereas actual slicks are distorted by wind, currents, and the pressure of new oil leaking from the source. The result is that predictions from spreading models and observations of actual slicks usually do not agree very well. For example, Blokker's spreading model (Reference N-2) predicts that in 24 hrs. the area of a crude oil slick will increase by a factor of 4, while some observations (Reference N-3) indicate that the increase is by a factor of 100.

Reference N-4 points out that most pure hydrocarbons do not spread spontaneously by surface forces. "Only aromatic and aliphatic hydrocarbons more volatile than n-nonane have positive spreading coefficients while none of the cyclic hydrocarbons will spread by surface forces." This may provide partial explanation of observations by Jeffrey (Reference N-5) and Hollinger and Manella (1973) which "have shown that with time one or more patches of thick oil (several millimeters thick) were surrounded by a much larger area of thin film, (less than 4 micrometers). Approximately 90 percent of the oil volume was located in these thicker layers that occupied only 10 percent of the visible slicked area of the sea." Reference N-1 also notes this phenomenon, as observed in the 1975 San Francisco Bay spill, where observations show that the area actually covered with oil may be only about 10 percent of the area spanned by the oil around its center of mass.

It is interesting to note the time of pancake formation in Jeffrey's experiment (2-2 1/2 days) agrees very well with the evaporation time for an average crude, as discussed in 1.2.1 below. If the mechanisms are coincident, then pancake thickness would be approximately that of a 1 or 2 day old slick.

1.2 OIL WEATHERING

The weathering of an oil slick is the result of evaporation, emulsification, and chemical and biological changes. Reasonably accurate models of these processes exist only for evaporation and even in this case the effects on evaporation of wind speed, temperature, and solar radiation are not well understood.

1.2.1 Evaporation

For a constant volume of oil, the rate of evaporation increases as the surface area increases and the slick thickness decreases due to spreading. Evaporation is also enhanced by sea turbulence which results from higher wind speeds and produces faster spreading and the ejection of oil from the surface as sprays and aerosols.

Analytical models of evaporation assume a slick of uniform thickness, perfectly mixed in all of its components, lying on a calm sea at $20^{o}C$ with no wind - clearly an idealized situation. Nevertheless, calculations based on this model give a lower bound for evaporation and indicate that as much as 30% of the initial volume of crude oil may evaporate in 2-33 hours (Reference N-2).

Reference N-5 shows a chart (reproduced in Reference N-1) of percent remaining vs. weathering time for the components of crude oil. The evaporation rate of each component depends on its concentration, which varies as lighter components evaporate off. Hence the entire set of volatile components of the crude oil must be taken into account in calculating its evaporation rates. As far as can be determined such estimates have not been made for the crudes likely to transit US waters in the future, for the sea conditions there prevalent.

An "average" crude was determined by Koons (Reference N-6) to consist of

Gasoline (C_5 - C_{10}) - 30%
Kerosene(C_{10}-C_{12}) - 10%
Light Distillate (C_{12} - C_{20}) - 15%
Heavy Distillate (C_{20} - C_{40}) - 25%
Residium (C_{40+}) - 20%

The evaporation of the lighter molecules, up to C_{14}, is approximately uninfluenced by the heavier ones, and they experience an exponential decay in concentration. As given in References N-1 and N-6, the times required for 90% evaporation are:

$<C_{11}$: 8.7 hours
C_{12} : 16.4 hours
C_{13} : 2 to 2.5 days
C_{14}: 5 days

A composite curve is given in Figure 10-5 of the report.

1.2.2 Emulsification

One of the most important and least understood of the processes affecting an oil slick at sea is the formation of water-in-oil emulsion. These emulsions may contain up to 80% water and may be 2 orders of magnitude more viscous than the oil alone. They spread more slowly and are less susceptible to weathering. When the water content is high they become semi-solid and grease-like (chocolate mousse). Emulsification is a weathering process that occurs 1-3 days after a spill. Its formation and subsequent fate are matters of conjecture. Whether chocolate mousse can be skimmed from the sea surface and pumped into storage containers is problematic. In any case, the recovered product may be mostly water.

The data of Reference N-6 are valuable as an approximation of the water-in-oil emulsion characteristics. They show that changes in viscosity and density are closely related to the changes in the amount of water in the oil, and are greater for oil undergoing natural weathering than for oil in sealed containers. For Kuwait crude and Iranian heavy crude, viscosity increased from 16 cs to about 316 in one day and to about 800 in

2 days of natural weathering. At the same time, however, Arabian light crude increased in viscosity from about 8 cs at the start to about 56. cs in 1 day and to about 80 cs in 2 days. In 7 to 21 days the Kuwait and Iranian oils had viscoisties in the 5,000 to 20,000 cs range, and the Arabian light had viscosities in the 500 to 5,000 cs range. Obviously, more experimentation is needed to cover the cases of concern for oil recovery.

2.0 CONCLUSIONS

It seems clear from the above that neither analytic or observational models of oil slick behavior are far enough advanced to warrant a detailed study of its impact on spill recovery operations. However, a few crude approximations may be of some use:

1) The center of mass of the slick moves in the direction and at the speed of the resultant of the local current vector and 3% of the local wind vector.

2) The linear dimension of the oiled area increases by a factor of 2 to 10 between 1 hour and 1 day after the slick has formed.

3) The volume of (crude) oil decreases by 30% or more after a few days through evaporation.

4) In turbulent seas this decrease may be negated by emulsification and formation of a "chocolate mousse" which would seriously impede recovery operations.

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